GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 8/6/80

Project Title: GEORGIA POULTRY INDUSTRY RESEARCH (FY81)

Project No: A-2704

Project Director: R.S. COMBES

Sponsor: GEORGIA DEPARTMENT OF AGRICULTURE

Agreement Period: From 7/1/80 Until 6/30/81

Type Agreement: STANDARD RESEARCH PROJECT AGREEMENT DATED 7/16/80

Amount: $240,000

Reports Required: MONTHLY LETTER REPORT; ANNUAL TECHNICAL REPORT

Sponsor Contact Person (s):

Technical Matters

Contractual Matters
(thru OCA)

Dr. John A. Cobb
GEORGIA DEPARTMENT OF AGRICULTURE
Agriculture Building
Capitol Square
Atlanta, Georgia 30334

Defense Priority Rating: NONE

Assigned to: TAL/AED (School/Laboratory)

COPIES TO:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director—EES
Accounting Office
Procurement Office
Security Coordinator (OCA)
Reports Coordinator (OCA)

Library, Technical Reports Section
EES Information Office
EES Reports & Procedures
Project File (OCA)
Project Code (GTRI)
Other

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION SHEET

5R/1

Date 12/29/81

Project Title: Georgia Poultry Industry Research (FY81)

Project No: A-2704

Project Director: R. S. Combes

Sponsor: Georgia Department of Agriculture

Effective Termination Date: 6/30/81

Clearance of Accounting Charges: 6/30/81

Grant/Contract Closeout Actions Remaining:

- [x] Final Invoice ~~and Closing Documents~~
- [ ] Final Fiscal Report
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other ______

Assigned to: TAL/AED (School/Laboratory)

COPIES TO:

Administrative Coordinator
Research Property Management
Accounting
Procurement/EES Supply Services
Research Security Services
Reports Coordinator (OCA)
Legal Services (OCA)
Library
EES Public Relations (2)
Computer Input
Project File
Other ______

FINAL REPORT

PROJECT A-2704

GEORGIA POULTRY INDUSTRY RESEARCH

PROGRAM MANAGER

Richard S. Combes, P.E.

AUTHORS

G. M. Battaglia
J. L. Clark, P.E.
R. S. Combes, P.E.
W. D. Holcombe
H. Z. Jackson, P.E.
R. M. Lamade, P.E.
L. J. Moriarty, P.E.
S. D. Robertson
C. C. Ross
M. S. Smith
G. E. Valentine
J. C. Wyvill, P.E.

Prepared for

Georgia Department of Agriculture

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, GA 30332

December 1981

Disclaimer

The Georgia Institute of Technology and the Engineering Experiment Station, and all technical sources referenced in this report do not (a) make any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; (b) assume any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report. The report does not reflect official views of policy of the above mentioned institutions. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Inquiries

Inquiries to Georgia Tech concerning this report should reference project A-2704 and be addressed to:

Director
Technology Applications Laboratory
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

ACKNOWLEDGEMENTS

The authors wish to acknowledge the abundant support received from Georgia's poultry industry in performing the research projects described herein. The assistance and interest offered has proven invaluable in successfully completing each project.

Special thanks is extended to Mr. Abit Massey, Executive Director of the Georgia Poultry Federation, for his tireless efforts in securing the necessary state funding and for acting as industry advisor and coordinator to this research. Thanks is also extended to:

Dr. John Cobb, Georgia Department of Agriculture
Mr. George Key, Strain Poultry
Mr. Jack Timms, Cyrstal Farms, Inc.
Mr. George Deadwyler, Wayne Poultry
Mr. Oakley Moore, Wayne Hatchery
Mr. Hubert Bunch, Gold Kist, Inc.
Mr. Tom Wilson, Gold Kist, Inc.
Mr. Lamar Hicks, Tyson Foods
Mr. William Wadell, Sr., Gold Kist, Inc.
Mr. George Fitch, Mar-Jac, Inc.
Mr. Jerry Lane, Mar-Jac, Inc.
Mr. Dale Morris, Mar-Jac, Inc.
Mr. Chet Austin, Tip-Top Poultry
Mr. Chuck Strong, Co-operative Extension Service

and the many other industry personnel who participated in these projects.

The authors would also like to express their appreciation to the many co-op students and student assistants of the Technology Applications Laboratory who provided invaluable assistance in completing this research.

TABLE OF CONTENTS

Page

Acknowledgements....................i
Table of Contents....................ii
List of Figures....................v
List of Tables....................vii
List of Appendices....................ix
Summary....................x

I. Wood Energy Applications....................1

Introduction
Site Description
System Description
Data Acquisition
Results
Economic Analysis
Conclusions
References

II. Feasibility Analysis of an Automatically Stoked Wood Fuel Combustion System for Heating Georgia Broiler Houses....................29

Introduction
Past Research
Systems Analysis
Wood Fuel Sources
Transport and Delivery of Wood
Storage of Wood Fuels
Wood Fuel Combustion
Design Concepts
The Deep Pit Concept
Grain Bin Concept
Economic Feasibility
Conclusions
References
Bibliography

III. Heat Recovery in Egg Processing Plants....................67

Introduction
Identification of a Recoverable Waste Stream
Identification of Process Utilize the Recovered Heat
Installation of the Heat Recovery Equipment
System Performance
Economic Analysis
Conclusions
Bibliography

TABLE OF CONTENTS (Continued)

Page

IV. Hatchery Heat Recovery....................................85

Introduction
Location of Site
System Description
Air Flow Pattern in the Setter Room
Energy Usage at the Wayne Hatchery
Heat Transfer Analysis
Data Aquisition
Economic Considerations
Results
Conclusions
References
Bibliography

V. Broiler House Energy Optimization..........................107

Introduction
Energy Conservation Technologies
Alternate Energy Technologies
Energy Optimization
Conclusions
References

VI. Energy Conservation in the Poultry Processing Industry......151

Introduction
Desuperheater System Capabilities
Storage Potential
Tank Specifications and Purchase
Energy Savings Due to Storage Capability
Future Work
References

VII. Solar Energy Applications..................................161

Introduction
Passive Solar Heating System
Active Solar Heating System
References

VIII. Computer Applications.....................................209

Introduction
Computer Uses in Producing Operations
Computer Applications in Processing Operations
References

TABLE OF CONTENTS (Continued)

Page

IX. Wastewater Treatment in Poultry Processing Plants...........235

Introduction
Procedure
Process Description of the Rotating Biological Contactor
Purpose of Study
Bench Scale Unit Description
Experimental Procedure
Results & Discussion
Economics
Calculations
References

X. Poultry Processing Noise Abatement Demonstration............267

Introduction
Laboratory Demonstration
Full Scale Plant Demonstration
Summary of Research Findings Relative to Noise Control
Conclusion
References

LIST OF FIGURES

Figure	Description	Page
I-1	Wood Fired Warm Air Brooding System	3
I-2	Furnace Specifications	4
I-3	Weekly Mortality in Control & Test Houses	13
I-4	Average Weekly Mortality	14
I-5	Wood Cost Sensitivity	22
I-6	Effects of Equity and Interest Rates on Payback Period	23
II-1	Flow Chart of Wood Fuel System	31
II-2	The Influence of Moisture on the Heating Value of Wood	39
II-3	Deep Pit Concept	50
II-3a	Side View of Conveying Pit	51
II-4	Forage Wagon Concept	54
II-5	Grain Bin Concept	56
II-6	Wood Cost Sensitivity	61
III-1	Typical Refrigeration Cycle	69
III-2	Heat Recovery System	72
III-3	System Installation Schematic	74
III-4	Heat Recovery System Installation at Crystal Farms, Inc.	75
III-5	Heat Recovery System Performance	78
IV-1	Hatchery Heat Recovery System	90
IV-2	Heat Transfer Process: Hatchery Heat Recovery	94
IV-3	Heat Recovery System Performance: Make-up Air Stream	102
V-1	Percent of the BTU Energy Used in U.S. Poultry Production	109
V-2	Effect of Housing Type and Season on Energy Input	110
V-3	Price Projections for Various Conventional Energy Sources	112
V-4	Comparison of Thermoneutral Temperature Range with Recommended	114
V-5	Double Curtain Design	122
V-6	Insulated Curtain Design	122
V-7	Solar Altitudes in Georgia	139
V-8	Wood Solar Energy Hybrid	143
VI-1	Desuperheater - Side View	152
VI-2	Desuperheater - End View	153
VI-3	Desuperheater Performance	155
VII-1	Solar Heated Broiler Growout House	163
VII-2	Completed Test Sections	167
VII-3	Test Section Elevations	169
VII-4	Installed Duct and Plenum	173
VII-5	Installed Glazing Frames	175

LIST OF FIGURES (Continued)

Figure	Description	Page
VII-6	Collector Outlet	177
VII-7	Completed Collector Modification	178
VII-8	Active Solar Collector	181
VII-9	Fan and Distribution Ducts	182
VII-10	Solar Broiler House	183
VII-11	Collector Performance for January 8, 1981	192
VII-12	Collector Performance for January 10, 1981	193
VII-13	Collector Thermocouple Map	195
VII-14	Measured Temperature	196
VII-15	Measured Temperature	197
VII-16	Flow Channel Exit Temperatures	199
VIII-1	Process Flow Diagram	217
VIII-2	Weigh Scale	225
VIII-3	Eccentric Shackle Design	227
VIII-4	Yoke Style Shackle	229
VIII-5	Typical Data Summary	231
IX-1	Overhead Schematic of Bench Scale RBC System	243
IX-2	Single Stage Substrate Removal	249
IX-3	COD Concentrations of Influent and Effluent	252
IX-4	Temperature Correction for BOD Removal	257
IX-5	RBC Construction Costs	259
X-1	Panel Arrangement in Reverberant Room	270
X-2	Measurement Points in Reverberant Room	272
X-3	Letter from the National Broiler Council	277
X-4	Percentage Change in Absorption Coefficient for Panel After Plastic Cover is Added	280
A-1	Poultry Engineering Progress	A-13
A-1a	Poultry Engineering Progress	A-14
B-1	Hot Water Storage Tank	B-3

LIST OF TABLES

Table	Description	Page
I-1	System Comparison	16
I-2	Wood Fuel Furnace System Capital Costs	16
I-3	Carrollton Wood House Wood Fuel Furnace System O&M Costs	17
I-4	Comparison of Alternative Fuels	20
II-1	Potential Supply of Wood Residues Available from Sawmills and Other Industries in North, North Central and Middle Georgia, 1980	33
II-2	Wood Fuel Properties	35
II-3	Comparison of Energy Available from Wood and Fossil Fuels on a Cost Basis	36
II-4	Typical Higher Heating Values of Some Wood and Fossil Fuels	38
II-5	System Comparison	58
II-6	Capital Costs for an Automatically Stoked Wood Furance System	58
II-7	O&M Costs for an Automatic Stoke Wood Furnace System	59
III-1	Economic Summary	81
IV-1	Hatchery Heat Recovery Economics	100
V-1	Proportion of and Average Fuel Usage in Broiler Production in Southeast	108
V-2	Insulation R-values of Various Materials	119
V-3	Age of Broilers and Roasters, Temperature and Ventilation Needs	126
V-4	Lamp Data	135
V-5	Recommended Illumination for Poultry Farm Industry Tasks	136
VII-1	Glazing Materials	172
VII-2	Assumptions for Economic Analysis of Solar Heating System	203
VII-3	Life-Cycle-Cost Factors for a 10 Year System Life	203
IX-1	Average Wastewater Characterizations for Test Plant	237
IX-2	Total and Soluable COD Concentration of RBC Feed	248
IX-3	COD Removal	250
IX-4	Loading	253
IX-5	Effluent Suspended Solids Concentrations	253
IX-6	Operating Conditions	254
IX-7	Energy Comparison of Biological Treatment Systems	262
X-1	List of Attendees Poultry Processing Noise Abatement Demonstration	269
X-2	Measured Sound Pressures Level Reductions with Panels Added	273

LIST OF TABLES (Continued)

Table	Description	Page
X-3	Absorption Characteristics of Test Panels and Reverberant Room	273
X-4	Surface Area Values Corresponding to Covered and Uncovered Regions of the Test Chamber	274
X-5	Calculated Sound Pressure Level Reductions with Panels Added	274
A-1	Energy Survey Results: Georgia Broiler Processors	A-4
A-2	Percent Change Over Previous Year; Georgia Broiler Processors	A-5
A-3	Energy Survey Results: Georgia Egg Processors	A-6
A-4	Percent Change Over Previous Year: Georgia Egg Processors	A-6
A-5	Energy Survey Results: Georgia Hatcheries	A-7
A-6	Percent Change Over Previous Year; Georgia Hatcheries	A-8
A-7	Energy Survey Results: Georgia Feed Mills	A-9
A-8	Percent Change Over Previous Year; Georgia Feed Mills	A-9
A-9	Energy Survey Summary: Georgia Broiler Processors	A-10
A-10	Energy Survey Summary: Georgia Egg Processors	A-10
A-11	Energy Survey Summary: Georgia Hatcheries	A-11
A-12	Energy Survey Summary: Georgia Feed Mills	A-11
B-1	Specifications Required	B-1
C-1	Site Visit Report	B-1

LIST OF APPENDICES

Page

A. Energy Consumption Survey and Poultry Engineering Progress Newsletter....A-1

B. Final Specifications: Hot Water Storage Tank for Gold Kist, Inc., Ellijay, GA....B-1

C. Site Visit Report....C-1

D. Interface Specifications Between HP-85 Computer and Datel Tape Reader....D-1

SUMMARY

Poultry is an important commodity in the economy of the State of Georgia. Nationwide, Georgia ranks first in overall poultry and egg production. During the past year, Georgia's poultry industry has been impacted by the economic maladies of the 1980's; spiralling production costs and stagnant selling prices. Opportunities exist, however, to cut production costs in poultry operations. Cutting energy consumption and increasing productivity are two areas where farmers and plant managers can look for answers. Reducing water consumption is another area where there are indications that substantial cost savings will be recognized before the turn of the century. As the poultry industry enters an era of technological enlightenment, more and more plants are hiring trained professionals to keep their operations current and competitive.

The Technology Applications Laboratory of the Georgia Tech Engineering Experiment Station has been supporting the poultry industry in its efforts to cut production costs since 1975. Through applied research, Tech has helped identify areas where:

- costs could be reduced either by implementing alternate energy sources and/or heat recovery technology or by reducing water usage and improving on site treatment;

- productivity could be increased through the utilization of computers on processing lines and the reduction of noise levels in poultry plants.

This report focuses on the research activities of the Technology Applications Lab for the period from July 1, 1980 to July 1, 1981 addressing the following activities:

Displacement of Propane by Wood as a Brooding Fuel Source in Broiler Growout Operations

A wood fired furnace supplying heat to a broiler growout house in Carrollton, Georgia has been operated successfully over the past year. Mortality records have been examined and subsequently compared to those for the conventionally heated control house. An economic analysis has also been performed using computer software developed by TAL personnel. Since the unit being demonstrated in Carrollton must be loaded by hand, a feasibility study was conducted to determine the economic attractiveness of utilizing an automatically stoked wood-fired furnace on a broiler growout farm. Three methods of fuel storage and conveyance were examined in depth. An economic analysis on one specific design was performed using the Georgia Tech computer.

Recovering Waste Heat from Superheated Refrigerant in an Egg Processing Plant

Waste heat has been successfully recovered from an existing egg cooler room refrigeration unit by inserting a heat recovery system between the unit's compressor and condenser. The recovered heat was subsequently used to preheat water going to the water heater and egg washers.

Recovering Waste Heat from Incubator Exhaust in a Hatchery

An air-to-air heat exchanger has been installed in a Georgia hatchery to demonstrate the feasibility of recovering energy from the hot, wet exhaust stream of an incubator and using the recoverd heat to maintain worker comfort. Temperature data were analyzed, and energy savings were estimated.

Energy Optimization of a Broiler Growout House

Opportunities to conserve energy in a curtain wall growout house operation have been examined. Past and present research has been reviewed and brooding, insulation, ventilation, lighting, location and orientation examined. Also examined, has been the usage of the sun and wood as energy sources. Computer optimization techniques for growout housing were also considered.

Addition of a Hot Water Storage Tank to an Existing Heat Recovery System

Because the availability of waste heat and the plant's hot water demand do not always coincide, a hot water storage tank has been specified for an existing heat recovery system located at a Georgia broiler processing plant. The installation of the tank will allow the system to recovery another 23 million BTU of useable energy.

Using Solar Energy to Displace Propane Requirements in Broiler Growout Houses

Design modifications to the passive solar collector located on a Cumming broiler growout farm have been completed. Further data has been gathered and analyzed on the active solar system located on a Villa Rica broiler farm. An economic analysis of the later system has also been performed.

Computer Applications

Research has been undertaken to evaluate the potential for using computers in a farm application. This includes intrafarm computational work and interfarm, intrastate communication of information. In addition to this work, Georgia Tech has completed installation and evaluation of a computerized yield evaluation system for poultry processing plants. The system was completely designed by Georgia Tech researchers and has proven to be an effective instrument for monitoring eviscerating line performance.

Wastewater Treatment

Research has been undertaken to determine the feasibility of using a rotating biological contactor (RBC) to treat poultry wastewater. The basis for selecting the RBC as a waste treatment system resides in its treatment effectiveness coupled with its low maintenance requirements and operating costs. Initial studies have focused on laboratory evaluation of the RBC's performance on poultry wastewater.

Poultry Processing Noise Abatement

After nearly three years of research, Georgia Tech has developed some interesting and workable solutions to the poultry processing noise problem. Efforts are being made to fully demonstrate these techniques in a Georgia plant and commercialization of at least one concept (noise abatement panels) is very probable. This research effort has drawn wide interest not only from Georgia's poultry industry, but from national concerns as well such as the National Broiler Council.

Energy Consumption Survey and Poultry Engineering Progress Newsletter

Results of the 1980 poultry industry energy survey have been tabulated and compared to the results from previous years. The mailing list for the Progress has also been updated and the newsletter circulated to Georgia's poultry industry to inform them of Georgia Tech's activities in poultry related research.

SECTION I

WOOD ENERGY APPLICATIONS

by C.C. Ross & M.S. Smith

Introduction

Three years ago the Georgia Tech Engineering Experiment Station designed and installed a wood-fired warm air furnace system on a broiler growout farm in Carrollton, Georgia. Funded by the Georgia Department of Agriculture through the Georgia Poultry Federation, the purpose of the project was to demonstrate the economic and technical feasibility of utilizing wood as an energy source for poultry brooding.

The log-burning warm air furnace became operational in June of 1978 and Tech engineers have been monitoring its performance since that time.[1]

Site Description

The farm consists of two identical growout houses which are physically located on a flat area approximately 100 feet apart and in an east-west orientation. They are approximately 5½ years old and are of wood frame construction with a sheet metal roof and roll asphalt siding. Three and one-half inches of fiberglass insulation equipped with a tri-ply vapor barrier are installed to form a ceiling across the growout area. Both houses are 325 feet long by 36 feet wide and have a nominal capacity of 15,000 birds.

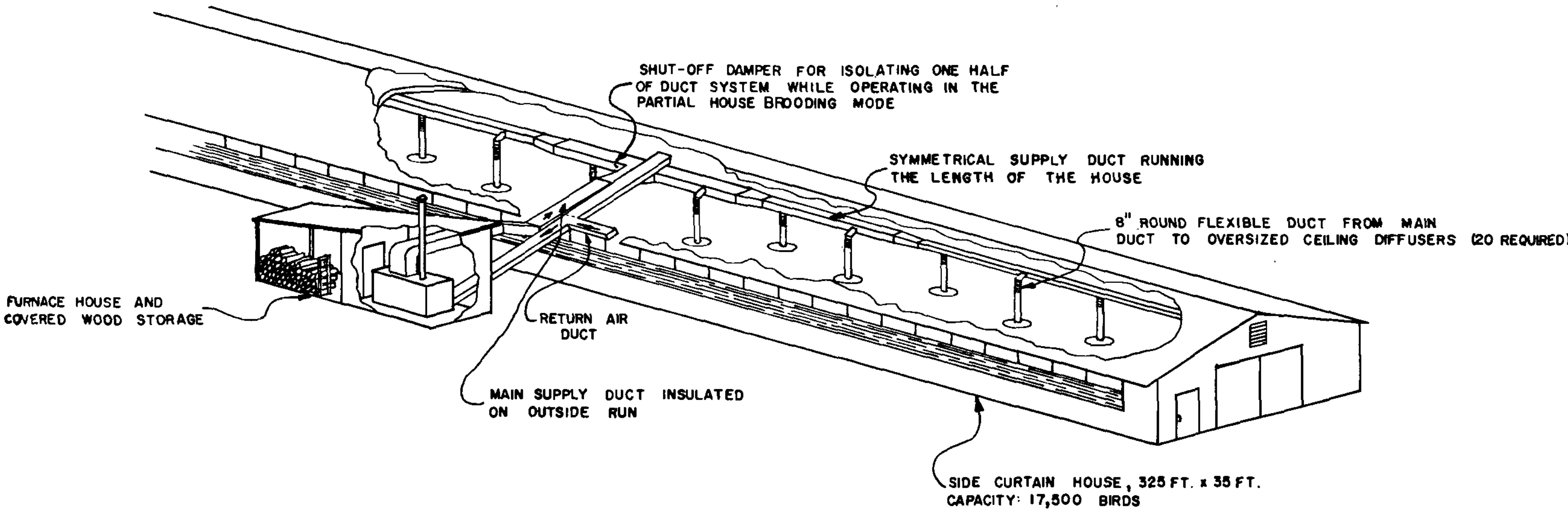
Each house has manually controlled, full length side curtains that employ a safety device to open the curtains in the event of a power outage. Feed for the chickens is supplied to both houses from a single storage hopper located between the two buildings. Once in the house, 2 feeders running the full length of the building supply the birds. Cup-type waterers are installed adjacent to each feed line. House temperature is regulated by five 36" swingout belt-driven exhaust fans. All five are controlled by thermostats and two are also equipped with timers to insure adequate ventilation for moisture and odor control.

The southernmost house is used as a control and has 20 conventional LP gas brooders with a heating capability of 30,000 Btu's per hour each. Although the other house has the same quantity and size LP brooders installed, they are used only as a backup system with the primary heat source being a 350,000 Btu per hour wood-fired furnace.

System Description

Figure I-1 depicts the main elements of the wood-fired warm air brooding system. A separate structure houses the furnace and its wood supply. The 3100 lb. furnace is supported by a concrete pad approximately 6 inches thick.

The furnace selected for this program was a Model 1007 log-burning unit designed and built by the Lynndale Manufacturing Company of Harrison, Arkansas. Figure I-2 shows a schematic drawing and a list of the specifications for the furnace. It comes fitted with a 47

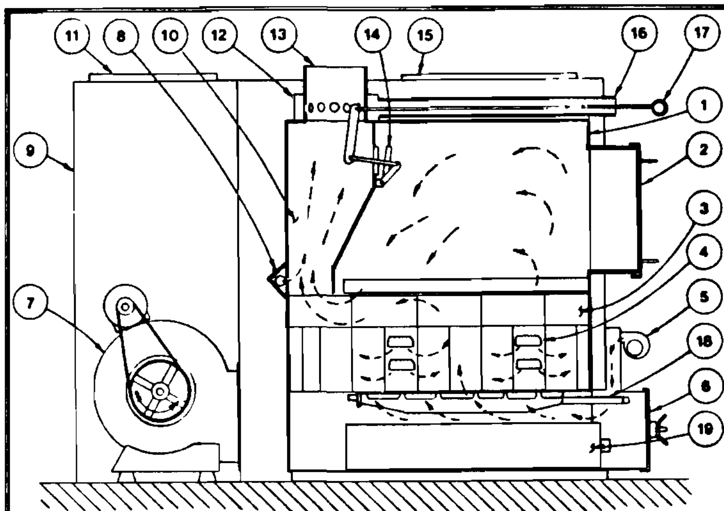


WOOD FIRED WARM AIR BROODING SYSTEM

STRAIN POULTRY FARMS, INC.
GEORGE L. KEY, GROWER

DRAWING IS NOT TO SCALE

FIGURE I-1



1. BLACK IRON FIRE BOX CASING
2. 3/8" PLATE FEED DOOR
3. 2 1/2" THICK FIRE BRICK
4. CAST IRON DRAFT LOUVERS
5. FORCED DRAFT FAN
6. 3/8" PLATE ASH PIT DOOR
7. BLOWER AND MOTOR
8. OXYGEN INTAKE
9. 24 GA. METAL CABINET
10. SECONDARY HEAT EXCHANGER
11. RETURN AIR DUCT OPENING
12. SUPPLEMENTAL AIR INTAKE
13. VENT
14. BYPASS SMOKE DAMPER
15. SUPPLY DUCT OPENING
16. SLEEVE FOR BYPASS SMOKE DAMPER
17. CONTROL ROD FOR BYPASS DAMPER
18. CAST IRON GRATES
19. ASH PAN

APPLICATIONS:

•RESIDENTIAL
BASEMENT, GARAGE, WORKSHOP, OR ABUILDING OF ITS OWN. THE LYNNDALE SYSTEM EVEN WORKS IN A MOBILE HOME.

•COMMERCIAL
FACTORIES, SHOPS, WAREHOUSES, RETAIL SHOWROOMS, SCHOOLS, WHEREVER HEAT IS NEEDED AT A REASONABLE COST, OR WHERE CURTAILMENTS ARE A PROBLEM, THE LYNNDALE SYSTEM WORKS!

•AGRICULTURAL
THE LYNNDALE SYSTEM IS HEATING CATTLE, HOGS, AND EVEN WORMS. • BUT TWO APPLICATIONS SEEM TO STAND OUT AS THE MOST POPULAR:

•POULTRY
THE BROODER HOUSE APPLICATION ALLOWS THE GROWER TO OPERATE PROFITABLY REGARDLESS OF THE HIGH COST OF HEATING WITH CONVENTIONAL FUELS.

•COMMERCIAL GREENHOUSES
HEAVY HEAT DEMANDS ARE NO PROBLEM WHEN YOU HAVE THE ECONOMY AND EFFICIENCY OF A LYNNDALE SYSTEM.

SPECIFICATIONS

MODEL	810	910	1007
BTU OUTPUT	125,000	200,000	350,000
FIREBOX (CU. FT.)	15	18	47
SHIPPING WT. (3 PC. SHIPPING)	1200 LBS.	1300 LBS.	3100 LBS.
UNASSEMBLED WIDTH	31"	34"	44"
ASSEMBLED WIDTH	34"	39"	46"
LENGTH	68"	73"	96"
HEIGHT	51"	51"	64"
FIREBOX METAL THICKNESS	10 GA.	10 GA.	7 GA.
FLUE SIZE	7"	7"	9"
BLOWER CFM	1600	2000	4140
MOTOR	1/3 HP 115V	1/2 HP 115V	1 HP 115V

FIGURE I-2

cu ft firebox and was rated at 350,000 Btu per hour at the time of purchase but is currently rated by Lynndale at 500,000 Btu per hour.[2] Air for combustion of the wood is supplied by a forced draft fan which operates when heat is required from the furnace. When heat is not required, the fan is turned off and the air supply to the firebox is minimized, thus starving the fire of oxygen and slowing the burning process.

House air to be heated is drawn into the furnace and circulated around the outside of the firebox by a 4140 cfm blower. Once it is heated the air is directed into the chicken house. The blower is controlled by the house thermostat; in addition, it will not operate if the temperature of the air entering the supply duct system is not above a certain set point.

Due to the physical separation of the furnace and growout houses, a short length of both the supply and return air ducts is exposed to ambient conditions. These duct runs are insulated and weatherproofed to minimize heat losses that can occur during inclement weather. The return air duct pierces the sidewall curtain and extends only a few feet out into the house, but the supply duct follows the incline of the roof to the ceiling where it branches out into two identical long runs down the length of the house. Flexible 8" diameter ducts are located at approximately 15 foot intervals to supply warm air at ground level. The air is distributed parallel to the ground by means of slightly oversized concentric ceiling diffusers.

It was desired to return heated house air to the furnace for use as makeup air. In order to do this it was necessary to remove dust and feathers from the air by filtering it. Manually operated and cleaned fitters like those used in home furnaces proved unacceptable because they clogged rapidly thereby requiring frequent maintenance. The decision was made to install an automatic roll filter manufactured by the Cambridge Filter Corporation horizontally across the return air inlet to the furnace.

The filter features a renewable filtering media which comes on a roll that is automatically advanced by a small electric motor. A differential pressure switch which is supplied as part of the filter's control panel senses the pressure on either side of the filter media. As the filter media clogs air can not pass through and the pressure switch detects a larger difference in the two pressure readings. When this pressure difference reaches a set point, the switch turns on the electric motor which pulls uncontaminated media across the return air inlet and takes up the used media on a storage reel.

The filter was installed in 1979 and has performed satisfactorily since that time. No mechanical difficulties have been encountered and filter media replacement has been infrequent.

One problem has surfaced though. The large amounts of dust and contaminants in the house air weigh the filter media down and pull it away from the guide located at the top of the filter, allowing unfiltered air to enter the furnace. This also neutralizes the effect of the differential pressure switch and the filter is not advanced as it should be. Hindsight shows that automatic filters such as the Cambridge roll filter should be mounted so their long axis runs vertically across the return air inlet, not horizontally.

Steps will be taken to alleviate this problem during the coming year.

The entire duct system was designed using the static regain method as recommended by ASHRAE in their Handbook of Fundamentals.[3]

A damper has been installed in the middle of the supply duct to facilitate half house brooding. Either half of the duct system can be shut down and the whole duct system can supply warm air to the growout area. Both sides of the system are sized generously to accommodate an increased air flow. The center location allows for symmetry and natural balancing for ease of operation.

Prior to the brooding of the first flock of chickens with the wood system, temperature and relative humidity data were recorded on a continuous basis in both houses using Rustrak Model 225 hygrothermographs. From the data collected it was determined that the test and control houses possessed parallel environmental characteristics and the control house could be considered an accurate data base with which to compare the performance of the wood heated house.

Due to the experimental nature of wood-fired poultry brooding in 1978 the 20 LP gas brooders were left in place in the wood-heated test house. These are capable of supplying 600,000 Btu's per hour to the growing broilers. The furnace was sized to maintain a 70°F house temperature when the outside temperature reached winter design levels for the Carrollton area. Any additional heat would be supplied by the brooders and in case of a wood system malfunction, the entire heat load could be handled by them.

No such malfunction has occured in three years of operation but when chicks are placed between the months of November and March the gas brooders are lowered into place during the first week of brooding. Although the brooders did not provide any heat (other than from the gas pilots) to the test house in 1978, they were utilized in 1979 and 1980.

Use of a warm air furnace provides the grower with a management technique that helps control relative humidity in the growout area. Compared to conventional LP brooders, a warm air furnace disperses dry, warm air into the space to be heated. The products of combustion (carbon dioxide and water) go up the furnace flue whereas with a brooder they escape into the house. The level of relative humidity should be lower in a house heated by a warm air furnace. Control of moisture levels is easier because moisture is not being added to the air everytime the heating system comes on. A drier environment could mean healthier chicks and could also reduce house ventlilation requirements.

The original scenario for the demonstration called for the grower, Mr. George Key, to provide the fuel wood himself. Typically, oak, hickory, elm, poplar, and yellow pine were available for harvesting on Mr. Key's property. During the first year of operation Mr. Key cut wood off his property for firing the furnace. A combustion analysis conducted on samples of this wood yielded an average heating value (dry basis) of 8,034 Btu per lb.

It was decided to measure wood usage on the basis of volume consumed. Special bins were constructed, each capable of holding 27.4 cu ft of wood. The date and time that each bin was started and finished was recorded so that annual usage could be estimated.

Part of the phenomena of modern poultry meat production is that the grower's operation has become a part-time job. Although the chickens require attention periodically each day, the time consumed will average 2 to 4 hours. As a result, many growers have full-time jobs elsewhere and raise chickens on the side. This leaves little time for cutting the wood required for a wood burning brooder house.

A more realistic approach then might be that the wood would be purchased rather than cut from the farmowner's land. A number of dealers and suppliers in the Carrollton/Carroll county area were contacted, and it was found that firewood was considered to be a home item and was priced accordingly. To be economically viable, it was found that wood would have to be purchased in pulpwood lengths and then cut in half at the site. Quoted prices for this wood varied from \$25 to \$40 per cord with the splitting fee averaging \$5 per cord.

Since pulpwood length is 5'6", cutting such a log in half reduces the length to 2'9", or 33", which can readily be accepted by the Lynndale furnace. The furnace can also accept logs up to 15" in diameter which reduces the log splitting required.

Bids to purchase 11 cords of wood were issued by Georgia Tech in 1979. The lowest bid received was \$42 per cord, delivered and split in half at the site. This wood was purchased and 3.67 cords of it were isolated and weighed prior to delivery. A combustion analysis yielded an average heat content of 8244 Btu per lb. of oven dry wood. But the wood also averaged 43% moisture by weight. This placed the energy available for heat from combustion of the 3.67 cords of wood at 94.8 million BTU. Since this initial purchase, Mr. Key has secured a supply of fuel wood at $32 per cord.

Data Acquisition

Gas usage is monitored by a gas meter placed in the LP gas line of each house. The readings are recorded daily by the grower. A timer is connected to the supply fan of the furnace which totals the number of hours that heated air is blown into the test house. This reading is recorded every week as part of routine energy data gathering. Timers are also connected to the motors of all the ventilating fans and these readings are recorded whenever data is taken. The temperature and relative humidity in each house are still continously monitored by the Rustrak Model 225 hygrothermographs.

Records of flock mortality are kept by Mr. Key and are readily available to Tech engineers. Unfortunately, Mr. Key utilizes one feed bin to furnish feed to both houses. No effort has been made by the integrator to calculate a separate feed conversion for the two houses; only an overall figure is determined. Tech is presently working with the integrator in hopes that a program can be set up that will enable the feed conversion to be monitored in each house.

As discussed earlier, wood usage is monitored by stacking it in five identical bins built to hold 27.4 cu ft each. Bin usage is recorded along with the gas meter readings.

Results

During a twelve month period between June of 1980 and June of 1981, the wood-fired furnace saved 1979 gallons of LP gas. The control house used 2092 gallons of LP gas to furnish its heat energy while the wood house brooders consumed 114 gallons. The balance of the test house's heating demand was met by burning 14.3 cords of purchased wood, primarily sweetgum and poplar.[4]

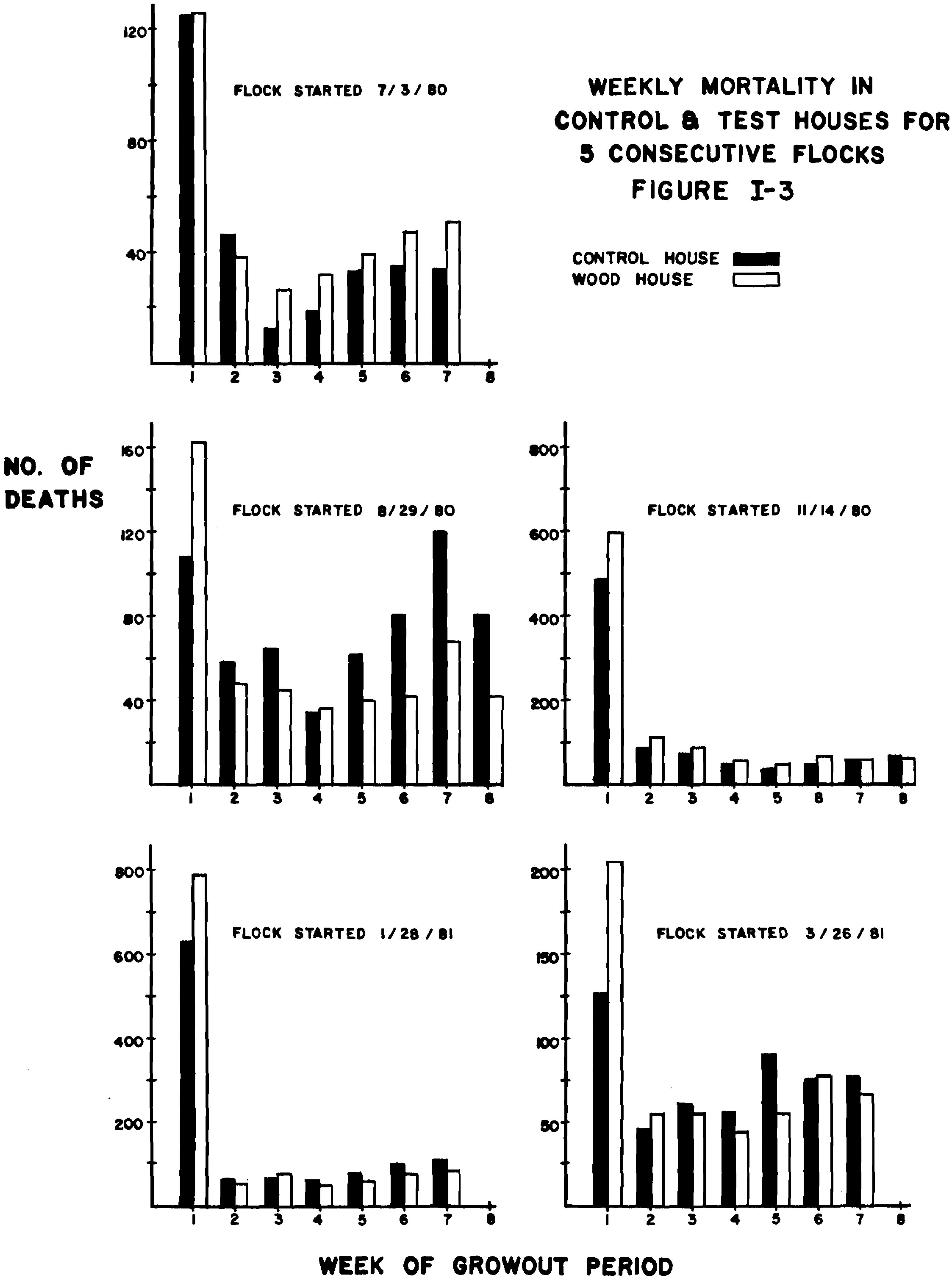
Over the time period of interest, the cost of wood remained constant at $32 per cord[5] while the price of LP gas escalated from $0.62 per gallon in May of 1980 to $0.75 by June of 1981.[6] Taking an average LP gas cost for the year of $0.69 per gallon and subtracting out the cost of electricity consumed by the furnace in providing energy to the wood-heated test house, a savings of $815.63 in energy costs was realized by the wood heater. Replacement of the chimney cap required a maintenance expenditure of $5.00 so the total savings for the 1981 fiscal year was $810.63. At the time the cap was replaced, the furnace flue was inspected and was found to be free from corrosion and creosote buildup.

An examination of mortality records for the five flocks raised during the past twelve months illuminated some interesting patterns.

Reference to Figure I-3 reveals a general tendency to lose more chicks during the first week in the wood house than the control house. However, in subsequent weeks the wood house survival rate improves and finally mortality levels fall below the control house. When weekly mortality totals were averaged for the five flocks, the results bear out this observation (See Figure I-4). At week five, the number of deaths in the wood house drops below those in the control house. If the deaths during the first week are neglected in both houses, total mortality for the five flocks is 10% higher in the control house when compared to the losses experienced in the wood-heated house. This tends to point to an advantage for the wood-heated house except during the first week where there is a possibility some system flaw is causing an increase in mortality. If this flaw could be identified and corrected the wood-heated house would produce more marketable meat than its control house counterpart.

During a year of average weather conditions (based on previous years' data) for the Carrollton area, the use of wood displaces 3261 gallons of propane. To do this, 26.5 cords of mixed hardwoods are burned. At the present price of LP gas, the wood-fired warm air system would save $1322 per year in energy expenditures and would pay for itself in only 5.1 years.

For the past year Mr. Key has purchased wood from the same supplier at a constant price. This spring he learned his source could no longer supply him with fuel wood. He is currently looking for a new wood dealer.[7] Due to the current interest in selling wood for



WEEKLY MORTALITY IN CONTROL & TEST HOUSES FOR 5 CONSECUTIVE FLOCKS

FIGURE I-3

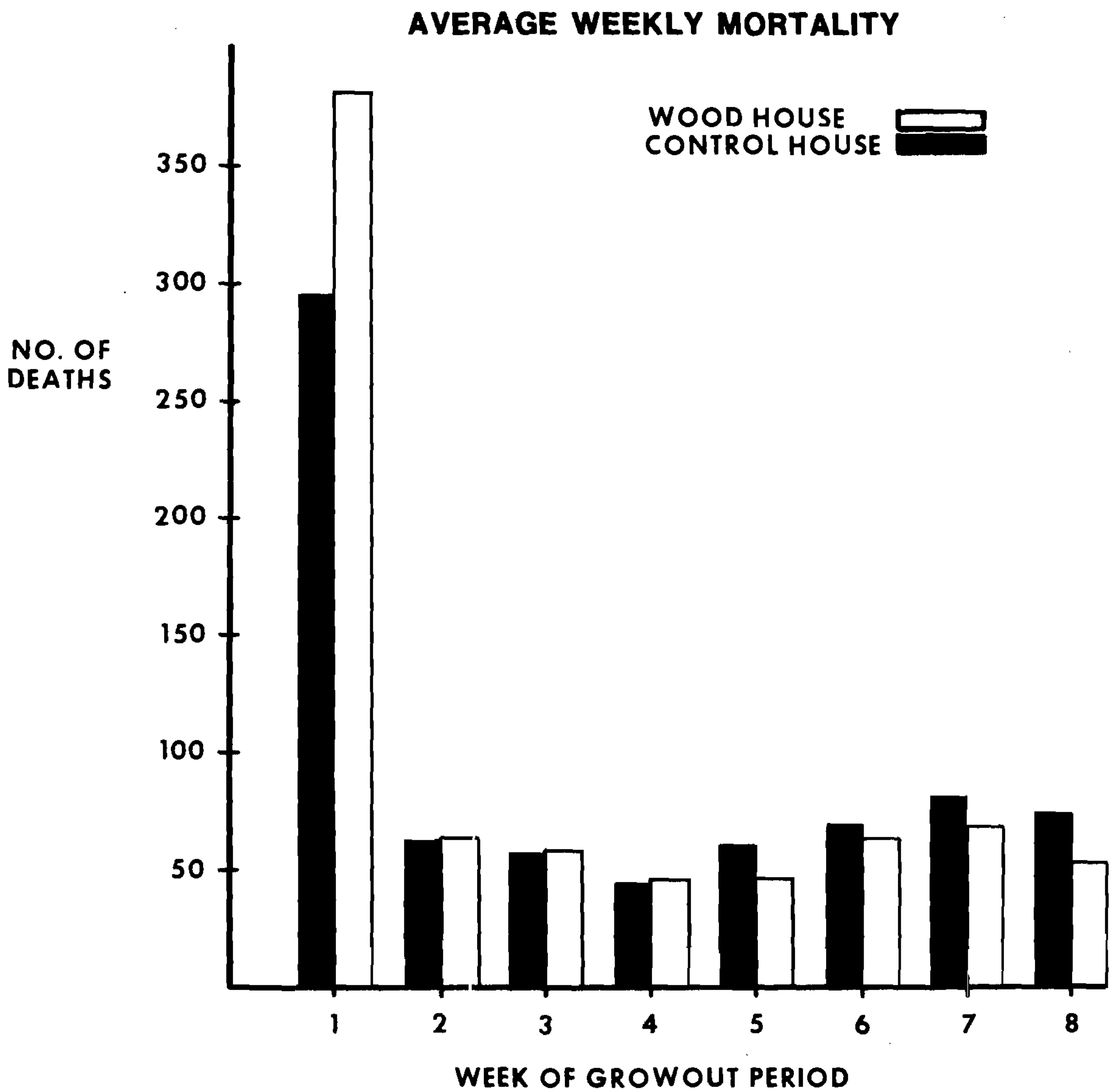

AVERAGE WEEKLY MORTALITY
WOOD HOUSE
CONTROL HOUSE
350
300
NO. OF DEATHS
250
200
150
100
50
1
2
3
4
5
6
7
8
WEEK OF GROWOUT PERIOD

FIGURE I-4

fuel it is felt that Mr. Key will have no difficulty in securing a new supply. However, it is expected that the price he pays for his wood will increase.

Economic Analysis

Past economic analyses of the wood energy system versus a LP gas system have been direct comparisons of life cycle costs over a 20 year period. The wood energy system would prove economically feasible using this method. However, because the wood system did not fulfill the total energy reqirements and a LP gas system would be a practical backup for cold weather brooding, the economic analysis format was shifted to a replacement analysis. In this analysis, it is assumed that the existing brooder system is left in place with only life cycle costs of fuel and maintenance (Table I-1) to be used in comparison with the life cycle costs of a wood energy system. Several different analyses were made under this replacement format using a wood energy computer economic analysis program. The computer program, WOOD 4, was developed by Georgia Tech and the Southern Solar Energy Center for industrial wood fuel conversion analyses.[8] Slight modifications were made for the light industrial use discussed here. The analyses also include available tax credits, tax rates, double declining depreciation, and different fuel and maintenance escalation rates. Other inputs include labor and insurance. Tables I-2 and I-3 illustrate estimated 1981 capital and maintenance (O&M) costs for a wood fuel furnace system like that in Carrollton.

Table I-1

System Comparison

	Wood System	Existing System
Capacity (output)	350,000 Btu/hr	600,000 Btu/hr
Fuel Type	Cut wood	LP gas
Unit Cost[1]	$32/cord	$0.69/gallon
Moisture Content (MC)	10% (wet basis)	-0-
Higher Heating Value	8,000 Btu/lb	91,000 Btu/gallon
System Efficiency	0.50	0.95
Life of System	20 years	20 years
Capital Cost	$8,800.00	-0-
Annual Operation and Maintenance Cost	$650.00	$30.00
Annual Fuel Use	26.5 cords	3,500 gallons

1 Delivered cost

Table I-2

Wood Fuel Furnace System Capital Costs
(1981 estimate)[1]

Furnace	$4,035
Installation (controls and shed included)	1,350
Duct System	1,200
Installed	540
Air Filter	725
Wood Splitter	800
Furnace Flue	150
Total Capital Cost	$8,800

1 Assuming 20 year life on everything but the furnace flue (5 year life)

Table I-3

Carrollton Wood House
Wood Fuel Furnace System O&M Costs
(1981 estimates)

Annual

Air Filter Media		$180
Furnace Flue		30
Electricity		80
[1]Labor		245
Misc (chainsaw maintenace and fuel)		65
[2]Insurance		50
	Total	$650

Fuel Costs
  Average wood use 26.5 cords/year
  Wood cost @ $32/cord or $850

1 Including ash removal; wood cutting; stacking and stoking @ $4.00/hr

2 Insurance - extra insurance cost over that of control house

Tax credits available include a federal investment tax credit of 10% and a federal alternate energy tax credit of 10% applicable to the total system cost. The Federal tax rate was assumed to be 25% and the state tax rate, 6%. There are no state tax credits available for wood energy systems.

Different escalation rates for fuel were assumed: 9% for wood fuel and 15% for LP gas. These assumptions are based on recent wood residue and fossil fuel cost increases. There are no possible methods of accurately predicting the future costs of either fuel. Escalation rates of 7% were chosen for both system's maintenance costs.

A discount rate of 16% was used in the program. The discount rate is used to determine net value and is generally considered to be the rate of return which an investor expects through other investment options. Such an option might be low risk Federal Treasury notes with interest rates of 13-14%.

Labor for wood preparation and handling is included for the first time. Time for cutting, stacking and stoking the delivered pulpwood and for ash removal was estimated to be 2.3 hours per cord. The use of LP gas fuel in the wood heated house during heavy load periods accounted for approximately 5% of total annual energy input into the house. Therefore, an average 95% reduction in LP gas fuel use has been realized in the wood heated house. The average annual LP gas fuel use of the control house was reduced 95% in the computer program to reflect this reduction in the economic analysis. The insurance cost is the additional cost over that for the control house. The rate is the same, but the wood system house value is higher. Mr. Key's insurance company approved the system expressing their opinion that it was as safe or safer than open flame propane brooders.

Table I-4 illustrates the results of an analysis for the systems described in Table I-1 assuming an equity of 100% of the capital costs (no loan). Payback of the total investment was 5.7 years with an internal rate of return (I.R.R.) of 27%. The internal rate of return is the discount rate at which the net present value equals zero and can be compared against the discount rate used in the program. It is considered a good investment if the I.R.R. is higher than the discount rate with a low investment payback period.

Figure I-5 illustrates the effect of changing wood prices on investment payback period and internal rate of return. This is under the assumption that the equity is 100% of the capital costs.

Figure I-6 illustrates the effects of various amounts of equity and different interest rates on the investment payback period for the system described in Table I-1.

A wood fuel cost of $32/cord and a 10 year loan period were assumed.

Conclusions

The savings generated by the wood-fired warm air furnace were down for the preceding twelve months as compared to previous year long periods. Although the weather in the Carrollton area during the

Table I-4

Comparison of Alternative Fuels
Cash Flow Analysis with Financing

(Thousands of Dollars)

	INSTALLATION	1	2	3	4	5
Equipment Cost	8.8					
Loan Proceeds	(0.0)					
Oil Costs		2.3	2.6	3.0	3.4	3.9
Wood Costs		.8	.9	1.0	1.1	1.2
Generated Electricity		0.0	0.0	0.0	0.0	0.0
Fuel Savings		1.4	1.7	2.0	2.3	2.8
Additional O&M		.6	.7	.7	.8	.8
Depreciation		.9	.8	.7	.6	.6
Interest		0.0	0.0	0.0	0.0	0.0
Pretax Income		-.1	.2	.6	.9	1.4
Taxes Payable						
State		.0	.0	.0	.1	.1
Federal		-.0	.1	.1	.2	.3
Tax Credits	(1.8)					
Net Earnings-After Tax		-.1	.2	.4	.7	1.0
Add Depreciation		.9	.8	.7	.6	.6
Deduct Loan Payment						
Net Cash Flow	(7.0)	.8	.9	1.1	1.3	1.5

TABLE I-4 (Continued)

SUBSEQUENT PLANNING CYCLES
(Thousands of Dollars)

	Years		
	6-10	11-15	16-20
Oil Costs	30.5	61.4	123.6
Wood Costs	7.8	11.9	18.4
Generated Electricity	0.0	0.0	0.0
Fuel Savings	22.8	49.5	105.2
Additional O&M	5.0	7.0	9.8
Depreciation	2.1	1.5	1.5
Interest	0.0	0.0	0.0
Pretax Income	15.7	41.0	93.9
Taxes Payable			
State	.9	2.5	5.6
Federal	3.7	9.6	22.1
Net Earnings-After Tax	11.0	28.9	66.2
Add Depreciation	2.1	1.5	1.5
Deduct Loan Payment	0.0	0.0	0.0
Net Cash Flow	13.2	30.4	67.7

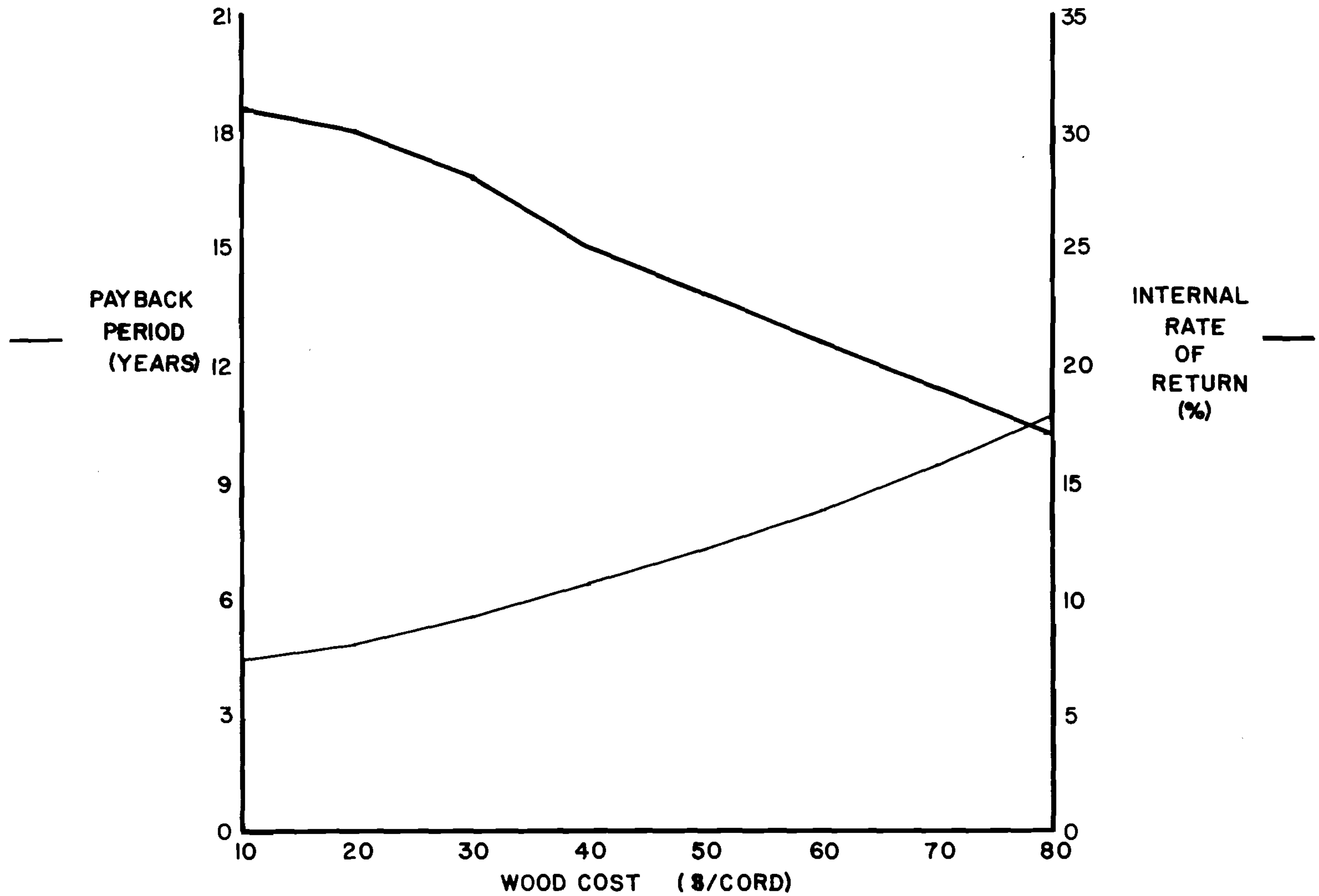
ECONOMIC VALUES OF WOOD FUEL ALTERNATIVE

CASH PAYBACK PERIOD OF INITIAL INVESTMENT = 5.7 YEARS

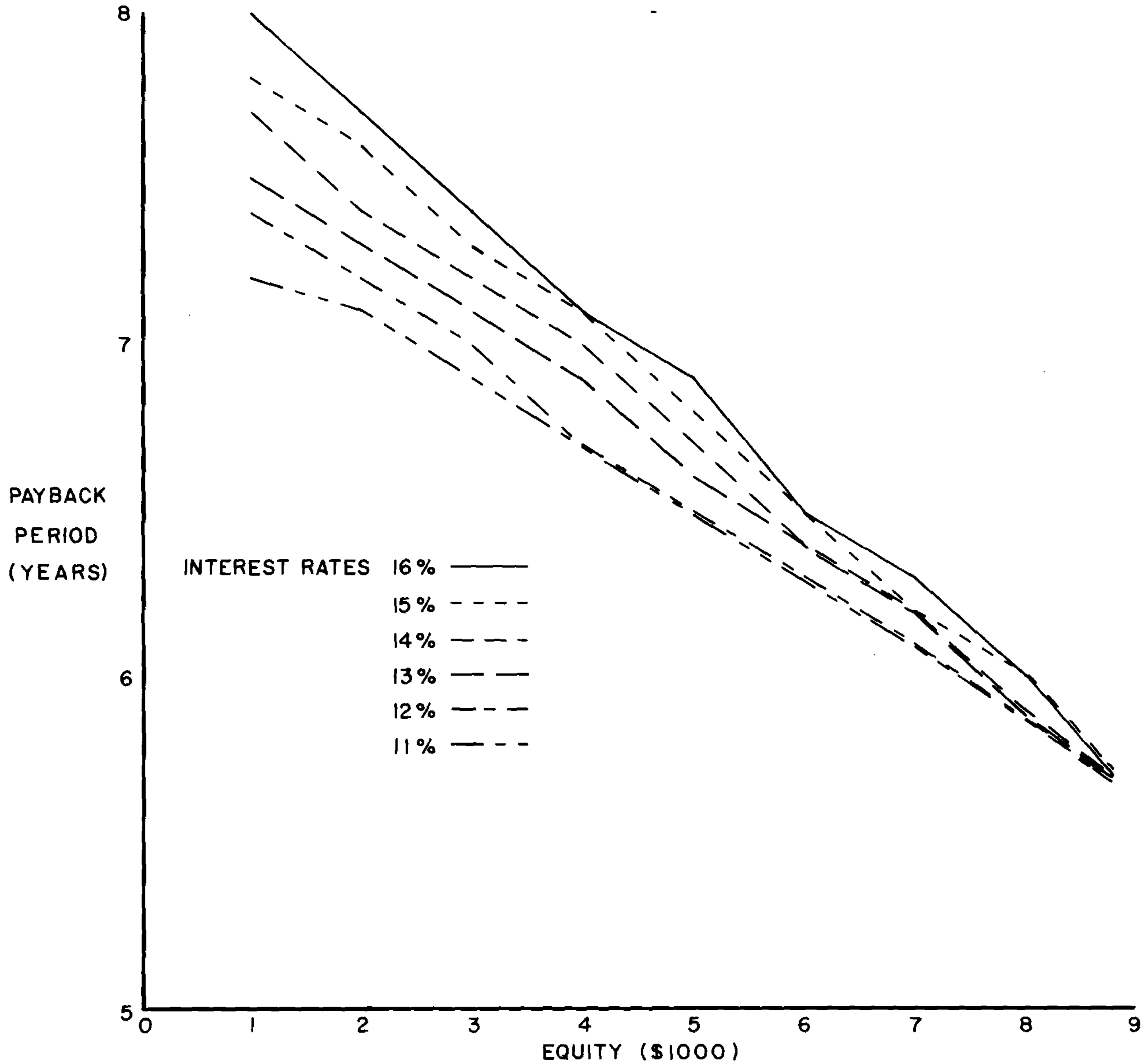
PAYBACK OF TOTAL INVESTMENT = 5.7 YEARS (CUMULATIVE CASH FLOW IS SUFFICIENT TO RECOVER INITIAL INVESTMENT AND REMAINING LOAN BALANCE)

NET PRESENT VALUE = 9.3 (DISCOUNTED AT 16.000%)

INTERNAL RATE OF RETURN = 27%



WOOD COST SENSITIVITY ($8800 EQUITY)
FIGURE I-5



EFFECTS OF EQUITY AND INTEREST RATES ON PAYBACK PERIOD
FIGURE I-6

current examination period closely paralled that experienced in recent years the demand for heat in both houses was down. How can the amount of heat necessary to provide thermal comfort actually decrease during a year of average severity? The answer involves the time at which the houses were occupied and heat energy was needed.

There were two winter time flocks during the test period, one started on the fourteenth of November and one begun on the twenty-eight of January. According to weather data for the Carrollton area obtained from the National Oceanic and Atmospheric Administration,[9] November and December of 1980 were slightly more severe than the year before, but January of 1981 was much more severe than January of 1980, logging 869 degree days as compared to 666. But both chicken houses were vacant between January 6 and January 28 so no energy was consumed during this period of high heat requirements. The second winter-time flock was started and February of 1981 proved to be much milder than February of the previous year. The next flock of birds was started on March 26 and the weather was so mild that only 300 gallons of propane were burned in the control house during the entire growout period. It takes the LP gas usage from these three flocks to come close to the amount consumed by the two winter flocks from the previous year; and those two flocks still burned 79 gallons more.

Although pleased that the wood house seems to possess an advantage in lower mortality after the first week of the growout period, Tech researchers are understandably concerned about the high number of initial deaths. Possible solutions are being considered.

- Are the chicks becoming dehydrated due to the lack of moisture in the heat source?

- Since air is returned from the growout area to the wood furnace, is the furnace harboring bacteria during idle periods and then supplying contaminated air when it is turned back on?

- Is the air diffusion pattern too small off of the duct system downcomers causing the young chicks to stack up and smother one another?

The grower, Mr. Key, told Tech engineers he has noticed a tendency for the young chicks to bunch under the downcomers causing some chicks to suffocate, so this could well be the problem.[10] The main thrust of next year's research effort at the demonstration site will be in reducing the initial high mortality in the test house.

The wood-fired warm air furnace continues to operate with a minimum of maintenance and upkeep. It has proved to be an effective source of heat for poultry growout operations, saving more money as the weather becomes more severe.

As interest in the use of wood as an energy source for poultry growout operations increases, the Carrollton demonstration project can be examined as a source of information for prospective users. Savings in energy costs are realized by using a reliable heating unit which possesses a distinct economic advantage when a grower is considering whether to install a new LP brooder system or a wood-fired furnace. In a situation where the wood-fired furnace is to replace an existing brooder system, the economics are much closer, but the wood system is still attractive. Other Tech research in the area of wood energy utilization and the experience of other groups and individuals illustrates that the labor intensive hand stoking of a log burning furnace is not the only way to utilize wood for heat. Automatically stoked systems are viable alternatives and are readily available from a number of manufacturers (see Section II).

Aside from the advantages wood possesses from an energy standpoint, it may also possess advantages in production. For the wood system to be a successful and accepted part of the broiler growout industry it must not affect performance adversely. What good are energy savings if a less saleable product is grown in the house?

Next year's research effort will also focus on quantifying the performance measures of broiler production at the Carrollton demonstration site. If wood heat is shown to be an effective source of energy from a production standpoint, implementation of wood-fired furnace technology will mean increased profits for Georgia's broiler growout farmers.

REFERENCES

1. Nolte, William, et.al, "A Wood Fired, Warm Air Broiler Brooding System," Paper delivered to the Southeast Region Meeting of ASAE, Feb. 1981, Paper No. SER 81-001, 25 pgs.

2. Personal Conversations with Mr. Randy Daniel of Lynndale Manufacturing, Harrison, Arkansas.

3. ASHRAE Handbook, "Air Duct Design," 1977 Handbook of Fundamentals, ASHRAE, New York, New York, 1978, pp. 31.1-31.36.

4. Law & Company, Combustion Analysis of Wood Fuel Sample Obtained from the George Key Broiler Farm, Atlanta, Georgia, June 1981.

5. Personal conversations with Mr. George Key, grower and owner of demonstration site.

6. Utility bills secured from Mr. George Key for propane bought, 6/1980-6/1981.

7. Conversation with George Key.

8. Engineering Experiment Station, Wood Energy Financing, Georgia Institute of Technology, Atlanta, Georgia, 1981.

9. NOAA, Climatological Data, Georgia, National Oceanic and Atmospheric Administration, National Climatic Center, Asheville, N.C., Vol. 84, No. 6-12, Vol. 85, No. 1-6.

10. Conversation with George Key.

SECTION II

FEASIBILITY ANALYSIS OF AN AUTOMATICALLY STOKED WOOD FUEL COMBUSTION SYSTEM FOR HEATING GEORGIA BROILER HOUSES

by C.C. Ross & M.S. Smith

Introduction

Because of rising propane costs and potential shortages, Georgia Tech, funded by the Department of Agriculture through the efforts of the Georgia Poultry Federation, designed and installed a wood-fired, warm air broiler brooding system on a poultry operation near Carrollton, Georgia (see Section I) in the summer of 1978. Results of the demonstration indicated that wood energy could be used economically in many poultry growing areas of Georgia.

The biggest single drawback to the widespread implementation of wood-fired warm air furnaces such as the one on the Carrollton farm is the amount of time the farmer must invest to cut, haul, and stack the wood. Even purchasing the wood does not eliminate all the required labor input.

In endeavors such as broiler growing where profit margins are low, it is important to minimize labor inputs. The manual stacking and stoking required by the furnace is labor that is not a necessary input to a conventional LP gas system. The present demonstration project has shown that wood is an economic and effective energy source for poultry brooding. The next logical step is to deal with the drawbacks of the present system and refine the approach to wood heating.

Past Research

Although wood fuel has been used by some industries for years, the technology for storage and handling of processed wood fuel is limited to large scale applications. Recently, research has been conducted to demonstrate the feasibility of small-scale automatically controlled wood fuel systems and established small-scale technology for storage and handling.

Since 1975, the Agricultural Engineering Department of the University of Maine has researched various aspects of wood chip storage handling and combustion for home and institutional space heating.[1,2,3] The result of such research has been the design of various heating systems ranging from 50,000 Btu/hour to 500,000 Btu/hour output. Other aspects covered by their research include storage box configuration, conveyor feed rate calculations, in storage drying of fuel, and wood fuel conversion of existing energy systems. One design was installed in the fall of 1980 at a junior high school in Gainesville, Georgia. Supervised by the Georgia Forestry Commission, the unit supplies low pressure steam for radiant heat in the building.

Systems Analysis

The flow chart in Figure II-1 illustrates the four major parts of a wood fuel system:

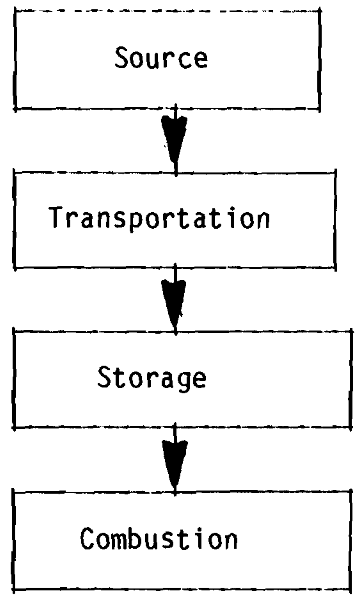


Figure II-1. Flow Chart of Wood Fuel System

A complete systems analysis is required to properly study the technical and economic feasibility of a complete wood fuel system.

Wood Fuel Sources

Wood Fuel Availability

There are three major types of wood fuel available in Georgia:

- wood chips
- wood residues
- wood pellets

Table II-1 shows the potential supply and prices of wood residues available from sawmills and other wood related industries as well as wood chip quantities and prices for north, north central and middle Georgia for 1980. Figures for wood pellet production were not available.

The total chip output of 42,487 tons per week is primarily whole tree pulp chips for paper making. At $15.92/ton weighted average price, chips are second only to wood pellets at $35/ton in unit cost. However, because of the lower yield and extra screening costs for reducing bark, needles and leaf content in pulp grade chips, this price is higher than for whole tree chips harvested solely for energy purposes. The flexibility and mobility of whole tree chips sources could make chips a more desirable source over less expensive wood residue fuels due to shorter distances and thus, lower transportation costs.

Wood residues have primary markets already established with paper, pulp, and agribusiness industries. Some residues are used already as a fuel. The market, however, is open for new areas of demand and significant amounts of residue are still either stockpiled or dumped. Of the residues listed in Table II-1, 10.2% of the bark, 7.8% of sawdust and 35.6% of other wood sawdust residues are available for recovery.

Wood pellets offer another source of wood fuel in Georgia. This fuel, made from densified wood waste, is capable of being used in most combustion systems using coal stokers. A major drawback to the fuel

Table II-1

Potential Supply of Wood Residues Available from Sawmills and Other Industries in North, North Central and Middle Georgia, 1980

Materials	Output	Weighted Average Price
	tons per week	dollars per ton
Other Miscellaneous Residue Materials[a]	16,555	4.01
Bark	10,930	4.02
Sawdust	17,785	4.14
Shavings	3,776	6.81
Subtotal	49,046	
Chips	42,487	15.92
Total	91,533	

[a] Residue materials in the "other" category include mixed sawdust and bark and wood scraps.

Source: Ames, Glen, Wood Energy Economics, 1980.

is its availability and high price, $35-$65 per ton. It does have a higher energy content and a lower moisture content than conventional wood chips (Table II-2) and does not degrade significantly, if stored properly.

Energy Values

The fuel value for wood will vary with the species of tree, moisture content and type of wood used. Although there is some variation in the heating value of different species, moisture content has the most effect on both the heating value and bulk density of a wood fuel. Table II.2 illustrates various wood fuels and their general properties.

Knowing both the net heating value (NHV) and combustion efficiency of wood fuels is important when comparing them with conventional fuels. Table II-3 shows a comparison of energy available from wood and conventional fuels based on combustion efficiencies and net heating values. Net heating values can be calculated by the formula:

$$NHV = HHV\,(1-MC/100)-MC/100 \times LH_2O \qquad \text{(EQ 1)}$$

where:

NHV = net heating value, Btu/lb

HHV = higher heating value, Btu/lb

MC = moisture content (wet basis) in %

LH_2O = heat required to vaporize and superheat one pound of water (assumed to be 1,200 Btu/lb)

Table II-2

Wood Fuel Properties

Wood Fuel	Moisture Content, Wet Basis	Net Heating Value, Btu per lb	Bulk Density, lbs/ft^3
Whole Tree Chips	50%	4,500	24.0
Dry Planner Shavings	13%	7,800	6.0
Green Sawdust	50%	4,500	20.0
Dry Sawdust	13%	7,800	11.5
Wood Pellets	10%	8,100	35.0

Source: Georgia Tech, A Feasibility Study for Wood Energy Utilization in the Southeast

Table II-3

Comparison of Energy Available from Wood and Fossil Fuels on a Cost Basis*

Fuel	Assumed Cost Per Unit	Assumed Combustion Efficiency	Estimated High Heating Value (BTU Per Unit)	Calculated** Dollars Per Million BTU
Coal (2.5%MC)	$55/ton	0.825	26,000,000	$2.63
Fuel Oil	$0.60/gal	0.80	150,000	5.00
Natural Gas	$0.003/cu ft	0.778	1,000	3.86
Wood Pellets (10% MC)	$35/ton	0.778	17,000,000	2.94
Wood Chips (47% MC)	$12/ton	0.67	17,000,000	1.99
Wood Residues (47% MC)	$8/ton	0.67	17,000,000	1.33
LP Gas	$0.70/gal	0.95***	91,000	8.10

* The figures are representative of those found commercially in 1979 in the Southeastern United States. Figures for specific locations may vary from those quoted.

**$/Million BTU = Cost Per Unit/[High Heating Value x Combustion Efficiency x (10MC/100)]

***Assumed 95% efficiency of combustion of open pancake brooder.

Source: SERI, <u>Decision Maker's Guide to Wood Fuel for Small Industrial Energy Users.</u>

Typical higher heating values (HHV) for various fuels are illustrated in Table II-4. The net heating value is the energy available for use after evaporation of the moisture. Figure II-2 illustrates the effect of moisture on net heating value. Combustion efficiency also changes with different fuels and can vary with different types of combustion chambers. Because of the consistency and larger exposed surface area of processed wood fuels compared to cut logs, an automatically stoked furnace will have a higher combustion efficiency (0.65 - 0.67) compared to a hand stoked unit (0.50 - 0.60).

Wood Fuel Preparation

Because of the small scale application of wood fuel on a farm and the high cost of processing equipment, the major portion of fuel processing to be performed at the fuel supply site. Preparation, in the form of screening and size reduction, is necessary to provide a medium for proper handling and combustion, particularly with smaller, fully automatic systems.

Passing the wood through a machine called a "hog" or a "hammermill" can reduce it to a required size for a certain handling or combustion system. Screening is used to separate oversized wood for reduction and remove foreign objects such as glass and metal. Wood fuel like sawdust and pulp grade wood chips may only require screening to be adequately prepared for fuel use. Use of a screen device at the farm storage site provides added protection against undesired objects like twigs and cans that could promote bridging and jam up conveyor systems.

Table II-4

Typical Higher Heating Values of
Some Wood and Fossil Fuels

Fuel Type	HHV (BTU/lb)
Southern Pine Bark	8,900
Hardwood Whole Tree Chips	8,600
Wood Pellets	8,600
Bituminous Coal	14,000
No. 2 Heating Oil	19,400
No. 6 Heating Oil	18,300
La. Natural Gas	21,800

Source: SERI, Decision Maker's Guide to Wood Fuel for Small Industrial Energy Users.

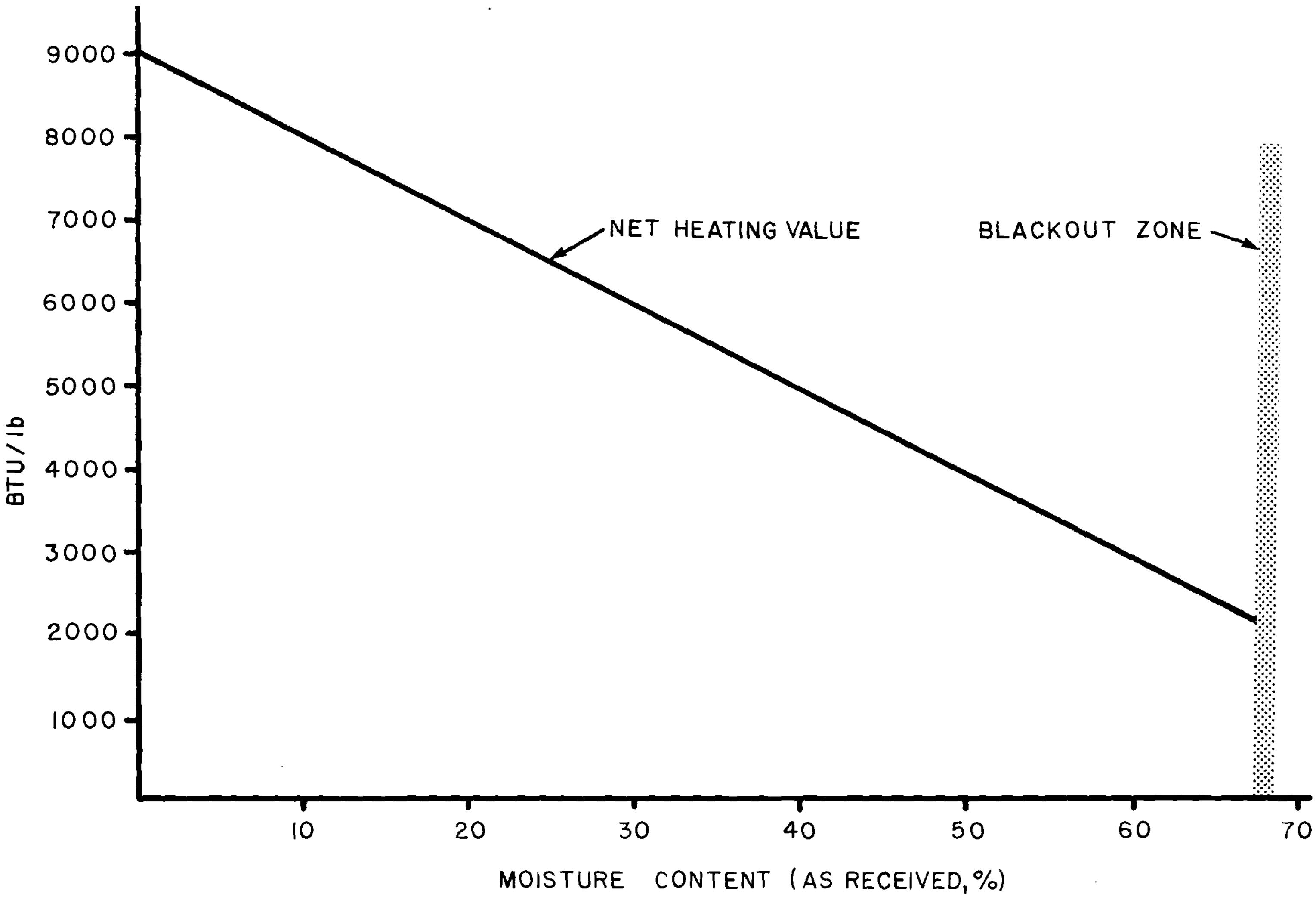


Figure II-2. The Influence of Moisture on the Heating Value of Wood
Source: Tillman, David A., Wood as an Energy Resource

Wood Fuel Contracting

Regardless of the economic attractiveness of wood, a continuous, dependable supply of wood fuel is necessary before it can be seriously considered as a replacement for conventional brooding fuel sources. Establishing a wood fuel contract and providing adequate storage are very important steps in guaranteeing a continuous supply of fuel, particularly during cold weather brooding. Current contracting is limited to direct contact with sawmill operations and to a few wood brokers under various pricing and supply conditions. An improved marketing system would be instrumental in providing adequate wood fuel supplies at stable prices. There are indications that such a wood fuel marketing system is developing in Georgia.

Transport and Delivery of Wood Fuel

The residue prices in Table II-I do not reflect transportation and delivery costs. These, of course, depend upon the location of the source relative to the farm and the mode of transportaion used. Some sawmills and other residue suppliers have their own means of residue transportation. However, delivery by either an independent trucker or the grower himself is likely to be the most practical means of wood fuel delivery to the farm. Cost per ton/mile of such delivery will vary depending upon the trucker and the size of the transported load. Transportation mediums can vary from 40 foot chip vans capable of carrying 20 tons of green chips to 6 ton dump trucks. Future demand for wood fuels could develop delivery systems similar to those for feed grain to the farm.

Unloading of the delivery truck will depend upon the type of storage chosen. Stationary above ground bins will require loading conveyors or augers similar to those already used for grain transport. In the case of a dump truck delivery, an agricultural grain conveyor with a feeder attachment could be used to unload the truck. Other forms of unloading include direct dumping either onto a slab or into a sub-grade pit. These methods are discussed later in this Section.

Arrangements for delivery frequency and timing should be made to guarantee adequate wood fuel quantity and quality.

Storage of Wood Fuels

Sizing Considerations

The size of wood-fired storage is determined by several factors:

- amount of fuel required
- delivery frequency and size
- storage cost
- site location

The amount of wood fuel needed is determined by the broiler house energy requirements, type of fuel used, local weather conditions and furnace or boiler efficiency. Most poultry integrators provide energy requirements for the house design and management plan that they require. Just as a grower uses this for determining the number and size of brooders be used, he can also use it to figure his maximum energy requirement for a cold weather flock. Using this and local weather data he can study the severity and length of cold spells for determining minimum energy storage requirements.

As seen in the earlier discussion on wood fuel energy properties, various fuels have different energy contents and densities at various moisture contents. Knowledge of the type and the range of moisture contents of the wood fuel to be used is necessary to ascertain what is an adequate supply.

Using the wet basis energy content and moisture content of a sample from a wood fuel source, an energy content per volume of fuel figure can be used with the house energy storage requirements to determine minimum storage volume requirements. This figure can then be used along with fuel delivery frequency and amount, and storage cost to determine the required storage volume. Rounding the size of the system to whole delivery units (above minimum storage requirements) will make delivery cost lower. Adding additional volume will provide some reserve capacity.

Design Considerations

Because of the physical nature of contained solids, storage will be the most likely of all the system components to cause problems. Due to this, some types of storage will not be possible with certain wood fuels.

Bridging, caused by friction between the wood and the storage sidewalls and by the internal compression loads of the wood fuel, will occur readily if the storage bin is not adequately designed. Design of a storage bin should include considerations for:

- internal bin configuration
- height of fuel in bin
- friction

Research has indicated that a bin configuration with a sloping sidewall of 60° opposite a vertical sidewall helps prevent a bridging arch from forming.[4] The length of such a bin is not as crucial as the width. Because of the increase in pressure within a wood fuel bin, a higher fuel level has a higher potential for bridging. Sidewall friction can be reduced with paints and treatments which also can prevent corrosion. Devices like flail chains and vibrators are available to prevent and break-up bridging if necessary.

Moisture content and particle size are important variables to consider in preventing bridging and other wood handling problems. Excess moisture in most solid wood fuels particularly sawdust and planer fines causes excessive caking in storage and will freeze in extremely cold weather.

Consistent particle size makes wood fuel easier to store and to meter accurately.

Unloading From Storage

Various wood storage and unloading systems for medium to large scale wood industry operations are commercially available. These systems use unloading and transport methods including:

- Chain conveyors
- Augers

- Belt Conveyors
- Front end loaders

However, most of these systems are much larger in size and cost for the small scale application of heating a broiler house.

Use of available agricultural grain and forage handling equipment may be possible to replace the more specialized and costly large scale wood handling equipment. This should not be done without some precaution given to the long term strength and continuous use capabilities of agricultural conveying systems.

Chain conveyors can be used effectively for unloading wood fuel, particularly if the conveyors are part of a live bottom storage system. The use of a single drag chain or several in parallel is effective in removing various types and sizes of wood fuel and can help prevent bridging problems. A conventional grain conveyor could possibly be used to transport wood residue to a furnace metering system.

Augers are also used in the agriculture industry for removal of grains from storage. The same principle used in the various methods of grain removal are also used in the wood industry for storage and subsequent removal of wood residues. Differences exist in that the wood industry systems are more wear resistant and can, up to a point, handle a wider range of particle sizes and moisture contents. However, processed wood fuel, especially wood pellets, could possibly be unloaded from storage by agricultural auger systems.

Agricultural type augers can also be used for conveying wood fuel to a furnace metering system. They can be more precise in metering than conveyors, but have restrictions regarding the distance over which material is conveyed and material size and quality.

Belt conveyors are useful for transporting unloaded material over long distances, but are not capable of retrieving material from the bottom of a deep storage pit. Both startup and maintenance costs could possibly be higher than comparable agricultural chain conveyor systems.

Front end loaders are frequently available on a farm and can be used for transporting wood fuel material from a storage pad to a furnace metering bin system. One drawback of this idea is the dependance on the farmer to operate the loader thus making the overall system somewhat less than automatic.

Metering from storage is a problem because of the changes in the energy value of the wood fuel and the uneven discharge rate from storage. Variable speed drives for a feeding system would help, but the expense is prohibitive. Changes in gear or belt ratios on the conveyor or auger drive and/or changes in the volume leaving storage by gate control can provide a reasonably accurate means of adjusting fuel feed rate. Care should be taken in sizing augers and conveyors to provide at least enough fuel to achieve the maximum heat output. Fuel size, durability and cost should also be considered when selecting conveying and unloading devices. A cover should be provided for an open conveying system to maintain fuel quality just as it should also be provided for the storage area.

Sizing and selection of motors and drives should be made with consideration to the load and wear conditions that exist in wood handling systems. Thought should also be given to available electrical service on a farm since many large electric motors require 3-phase service.

Wood Fuel Combustion

Metering Bins

Once fuel material reaches the furnace, a metering bin may be used to take up slack in the system and provide a more accurate and reliable fuel metering system. However, because of cost and the absence of a real need for such accuracy, this device is optional.

Stoking Devices

There are various ways for introducing wood fuel into a combustion chamber controlled primarily by fuel type and size. Sawdust and other consistent wood particles, like sander dust and small wood chips, can be used with existing crushed coal underfeed stoking devices. Slanted grate systems with below grate forced draft also are used with automatically stoked combustors. This type of design can be used with less homogeneous fuels than the underfeed system. Use of an airlock to provide controlled combustion air and protection from pre-ignition of fuel in the conveyor system is common on many of these systems.

Ash and Emission Problems

With the ash content of clean wood fuels typically being about 0.5%, removal is usually by hand and is not a major problem. However, sand and grit from logging or from careless loading at the source can bring the ash content up to 5% which can cause problems both with the grates and ash removal. Various grate designs are being employed to prevent these types of problems. Some of these designs are still being tested.

Creosote condensation resulting from low stack temperature and poor flue design can also cause problems. This buildup results in restricted draft and a possible fire hazard if not carefully watched and corrected.

Emission controls under current Georgia air quality standards are not required for combustion systems below 9-10 million Btu/hr total output. However, the combined output of several furnaces or boilers could violate air quality statutes. Consultation with the Air Quality Control section of the Georgia Department of Natural Resources is recommended if this possibility exists.

Controls

Controls are necessary for automatic storage unloading and subsequent stoking. These should include:

- Conveyor feed on and off control
- Combustion air control

- Combustion chamber ignition control
- System lock-up safety switch
- System failure alarm

Because the storage unloading and conveying system is not variable speed, a control to turn conveyors off and on is needed. This control monitors combustion chamber temperature and brooding area energy demand to provide a set amount of fuel. Adjustment for house and combustion chamber temperature lag and varying fuel energy content is necessary to maintain maximum loading and combustion efficiency.

Combustion air control is also necessary to provide air to the combustion chamber on an as needed basis. It also aids in reducing combustion to a smolder during low demand. Combustion air and air lock control is a safety feature that can be used to prevent pre-ignition of incoming wood fuel. Control of the combustion igniter is necessary to maintain combustion when the house load fluctuates from smolder to full fire.

Series connection of all unloading and conveying drives should be made to prevent either spillage when one drive is incapacitated or continuous run of a drive when fuel is not being delivered up the line. In addition to this, an alarm, similar to those used to signal a power failure, should be installed to guard against system mechanical and electrical failures.

Design Concepts

Because of the high costs associated with small-scale wood fuel storage and handling systems using conventional wood industry methods, several alternatives have been explored. Three different concepts are illustrated below:

- Deep pit design
- Forage wagon design
- Grain bin design

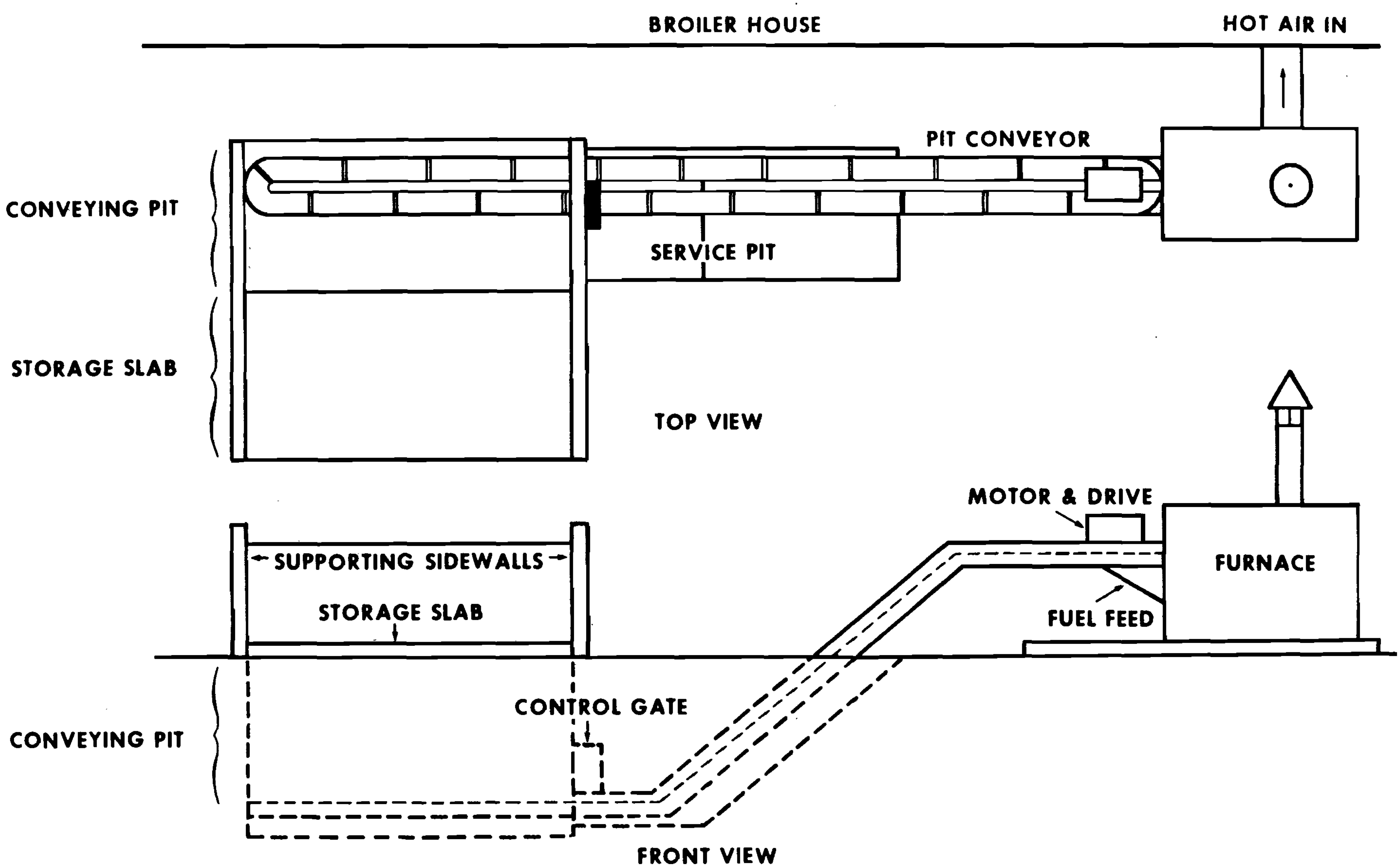
Only the forage wagon design is known to be undergoing tests. The other two are unproven in performance and capability.

The Deep Pit Concept

The deep pit design is based primarily on an above ground design developed by the University of Maine.[5] Figure II-3 illustrates the main components of the system including:

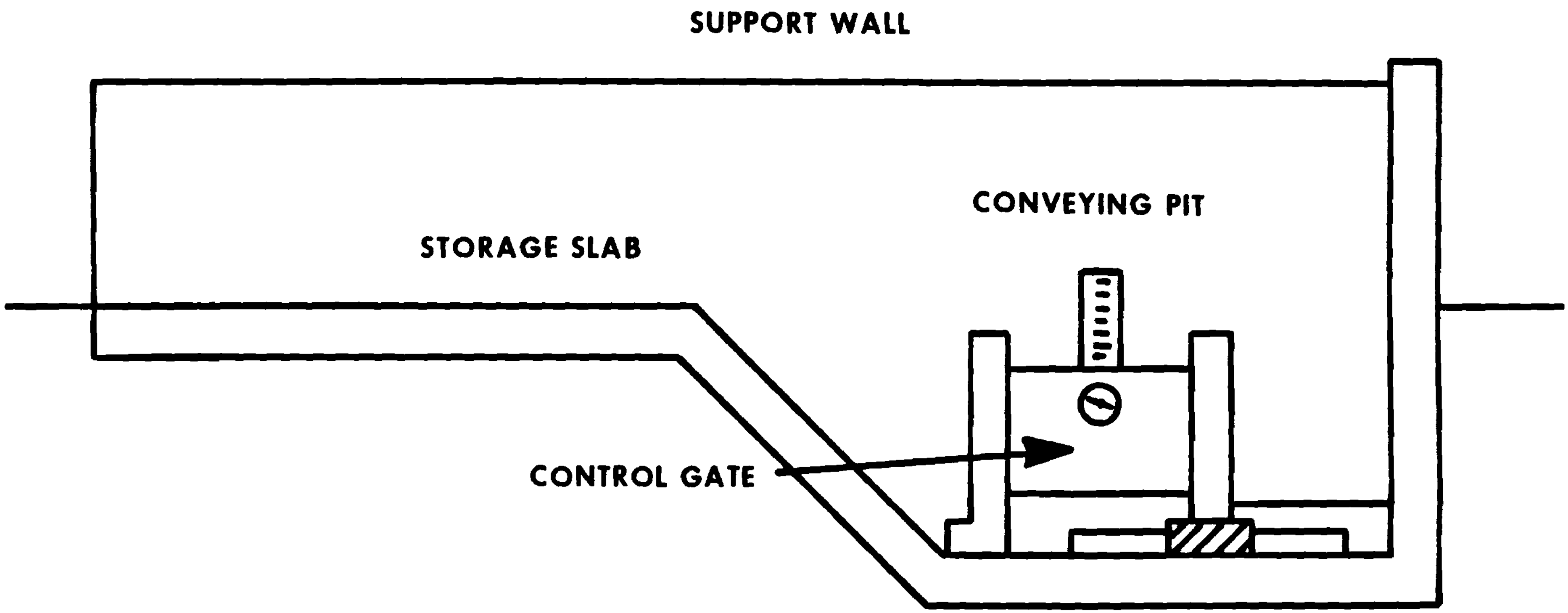
- Storage slab
- Conveying pit
- Pit conveyor

The conveying pit is designed with a 60° side wall and a straight opposite wall to help reduce bridging. The width of the pit is limited by this angle and the allowable depth. The length of the pit is restricted by the cost of the additional length of the pit conveyor. If a small front end loader or scraper blade is available,



DEEP PIT CONCEPT

FIGURE II-3



SIDE VIEW OF CONVEYING PIT

FIGURE II-3a

the pit could be reduced in size to hold a minimum of one day of storage and the fuel could be scraped periodically from the storage slab into the pit by the loader. This would significantly reduce all pit dimensions. The pit should have adequate drainage to prevent structural and mechanical degradation.

Three inches of reinforced concrete is recommended for the storage slab and the pit floor. The sidewalls and end wall are formed by sheets of treated plywood with treated posts spaced according to the load determined by the final length and width dimensions of the pit.

A flexible cover should be fitted to the pit to protect the wood fuel from the elements. It should be easily removable to allow fuel delivery, pit loading, and service.

The pit conveyor is a side return conveyor used primarily for manure handling, but has been used for residue handling in the wood industry. The conveyor pulls the residue from the pit through the control gate, on to the furnace, returning the unused portion. The whole conveying system uses only one motor and drive to retrieve and stoke the wood residue into the furnace. The conveyor is not variable speed; therefore, the feed rate would be varied by using the control gate to change the volume of material leaving the pit.

The primary advantage of the pit design is its easy loading. Loading only requires that a dump truck back up to the pit and dump its load. Other advantages include:

- Simple, rugged design
- Inexpensive storage

Disadvantages include:

- Depth restricted by local water table
- Limited access to pit conveyor
- Expensive conveyor system

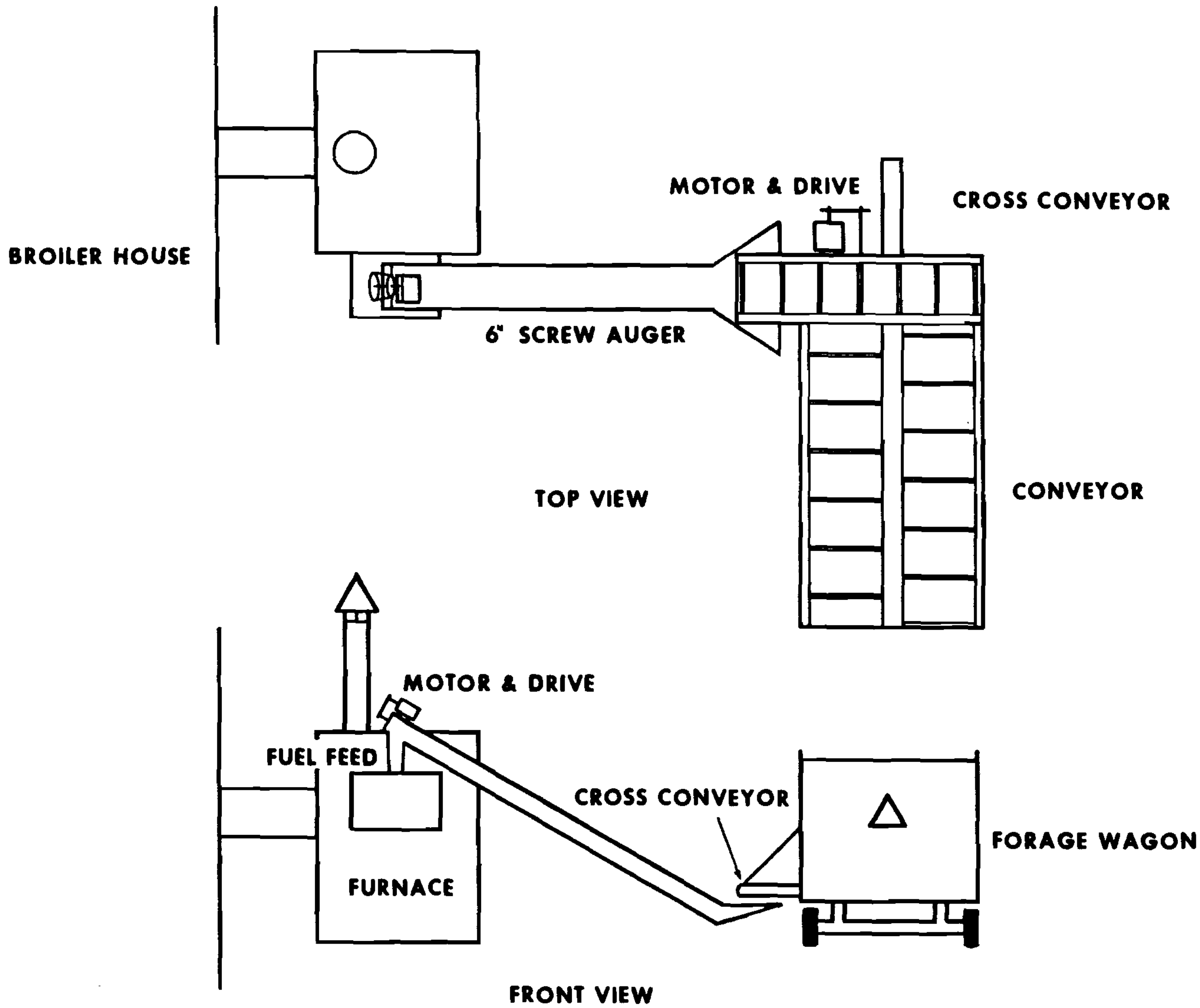
Forage Wagon Concept

A wood energy concept currently under testing by the Georgia Foresty Commission utilizes an agricultural forage wagon for storage, and conveying of wood chips. Figure II-4 illustrates the system components.

The forage wagon has a full length conveyor system which moves the wood chips toward the front of the wagon. As the chip pile approaches the front, rotating beaters push the chips into a cross conveyor that moves them outside the wagon. At this point they are conveyed by a flighted chain conveyor to the air lock entrance of the furnace. An electric motor and drive is used to power the forage wagon conveyors and is controlled, along with the electric motor and drive of the flighted chain conveyor to the furnace, by demand and furnace temperature.

Advantages of this sytem include:

- Lack of bridging
- Multiple use of forage wagon
- Automatic operation



FORAGE WAGON CONCEPT

FIGURE II-4

Disadvantages include:

- Small storage size
- Separate device for loading wagon

Grain Bin Concept

Utilization of a wet grain feed bin for fuel storage may be possible with low moisture and consistently sized sawdust and wood pellets. Figure II-5 illustrates the concept components.

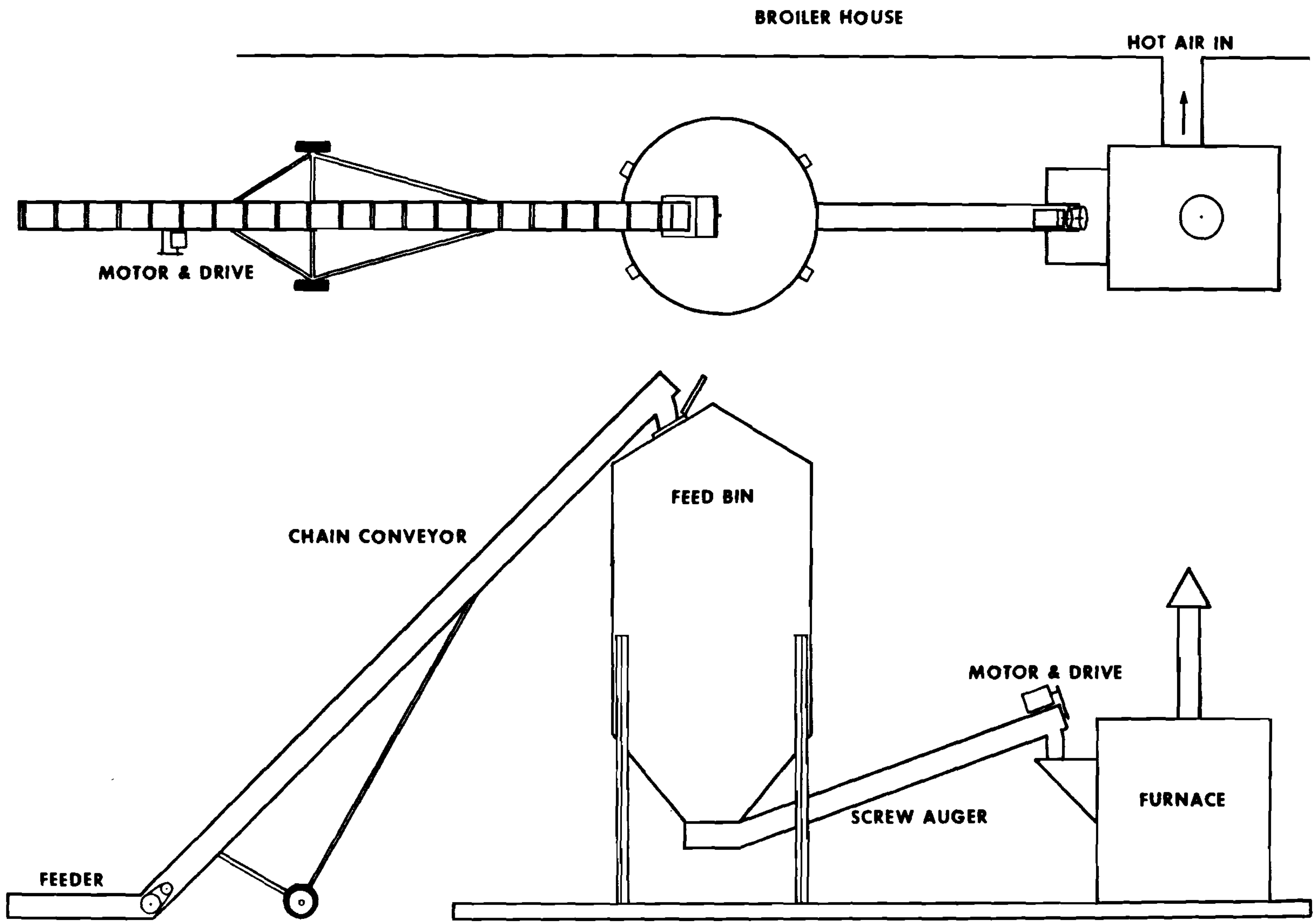
The bin is loaded using an agricultural auger with a feeder attachment taking fuel from a delivery dump truck. Once the fuel is loaded from the top, it can be unloaded from the bottom by an underfeed auger which conveys the fuel to the entrance air lock on the furnace. Removal of fuel from the bin will probably require an agitation device much like those used in the feed handling industry for wet grain.

Advantages of the system include:

- Easy access to equipment
- Use of familiar, multi-use equipment
- Automatic operation

Disadvantages include:

- Bridging probable with sawdust
- Slow loading rate



GRAIN BIN CONCEPT

FIGURE II-5

Economic Feasibility

Table II-5 illustrates a potential comparison of an automatically stoked wood fuel furnace system replacing a conventional LP gas brooder system for the wood heated Carrollton test house in Section I. Comparisons could be made to either place a wood heated system or a conventional LP gas system in a new house or replace an existing LP gas system with a wood heated system. The wood system in Table II-5 is sized to use the replaced LP gas system as a backup for cold weather brooding. This wood system is assumed to satisfy 95% of the annual heating load. A grower may wish to size his furnace system larger to use only wood fuel and totally replace any LP gas system. At the moment, however, solid fuel sytems are not as reliable as LP gas or natural gas fueled systems because of the effects of electrical power outages or mechanical failure. There is also an added danger of massive losses if the wood system fails.

Table II-6 and II-7 detail estimated capital, maintenance and feed costs for the wood fueled system in Table II-5. Many components of the system, such as the ductwork, are identical to that used in the Carrollton project in Section I. Other assumptions for maintenance costs and the existing propane system fuel and maintenance costs were also made from experience gained on this project.

To develop a total economic comparison for the wood-fired system a computer program for larger industrial wood fuel conversion economics was used with slight modification. A life cycle cost analysis with outputs of payback period, net present value and

Table II-5

System Comparison

	Wood System	Existing System
Capacity (output)	500,000 Btu/hr	600,000 Btu/hr
Fuel Type	Sawdust, wood chips	Propane
Unit Cost***	$8/ton (green)	$0.70/gallon
Moisture Content (MC)	50% (wet basis)	-0-
Higher Heating Value	8,000 Btu/lb	91,000 Btu/gallon
System Efficiency	0.65	0.95
Life of System	20 years	10 years*
Capital Cost	$18,200.00	-0-
Annual Operation and Maintenance Costs**	$580.00	$30.00
Annual Fuel Use	58 tons	3,500 gallons

* Brooders left in place for backup, assumed to have 20 year life
** Includes labor, electricity, replacement parts, filter media, insurance
*** Delivered cost

Table II-6

Capital Costs (1981 estimates)
For An Automatically Stoked Wood Furnace System

Furnace (Installed)	$9,350
Duct System (Installed)	1,950
Wood storage & conveying system (Installed)	6,000
Air Filter	750
Flue	150
Total Capital Cost	$18,200

Table II-7

O&M Costs (1981 estimates) for an
Automatic Stoke Wood Furnace System

<u>Annual</u>

Filter media		$180/year
Electricity		180
Mechanical Repair		100
Labor*		40
Furnace Flue		30
Insurance**		50
	Total O&M Costs	$580

Fuel Costs

Annual load = 3500 gal LP gas/year x 91,000 Btu/gal x 0.95 (eff)

= 3.02575×10^8 Btu/year

3.02575×10^8 Btu/year = 4,000 Btu/16 x 2000 lb/ton x M tons x 0.65 (eff)

M = 58.2 tons

* Labor: 2 hr/flock (remove ashes, other) x 5 x $4.00/hour = $40

**Insurance cost is the difference between that for identical houses using different heating systems.

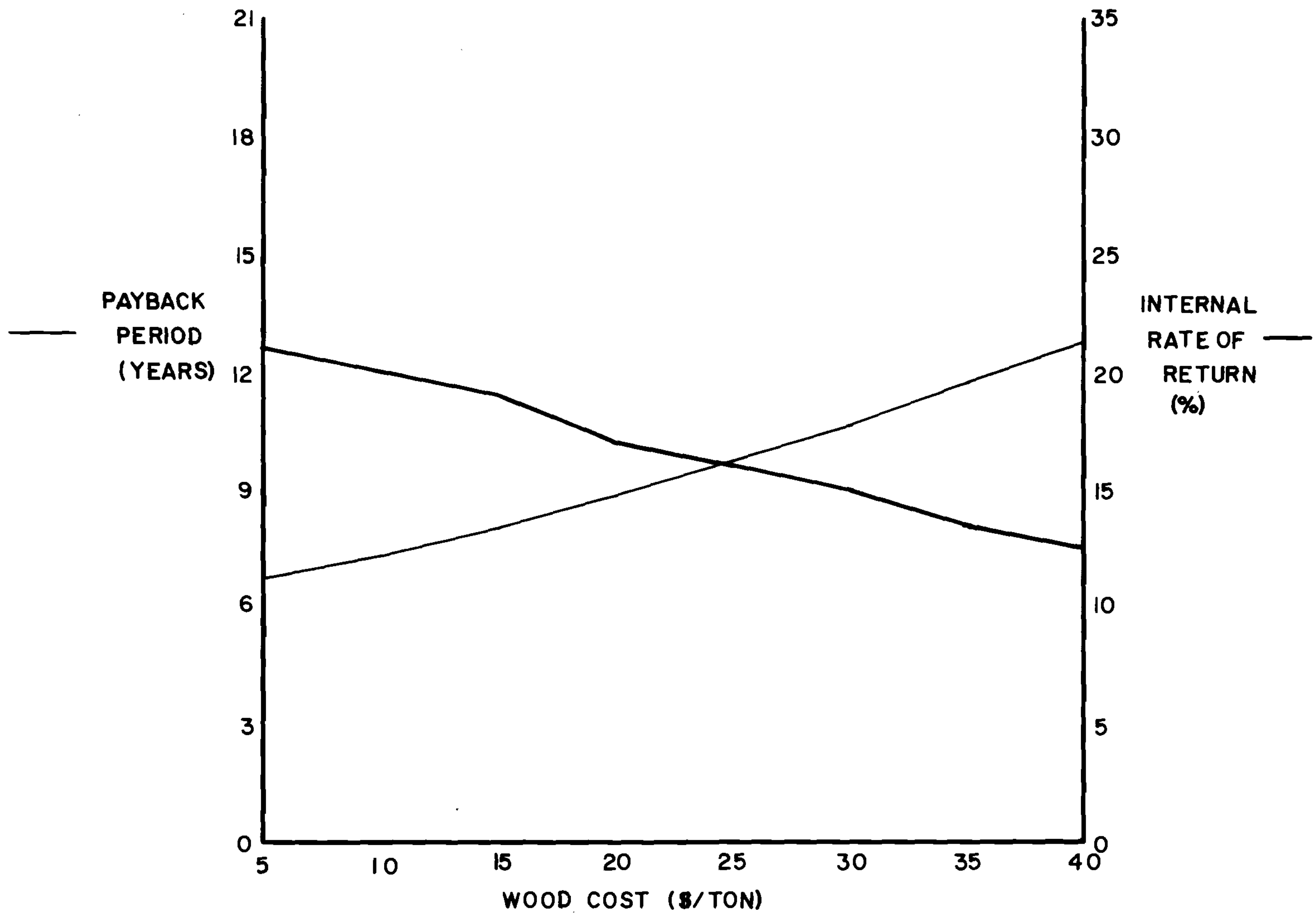
internal rate of return is contained in the program and is repeated using different wood fuel costs and an assumed full capital cost of $18,200.

Assumptions in the program include:

- 10% federal investment tax credit
- 10% federal alternate energy tax credit
- 7% maintenance (O&M) cost escalation rate for both systems
- 9% wood fuel cost escalation rate
- 15% propane fuel cost escalation rate
- 16% discount rate
- 20 year replacement system life
- double declining depreciation

The federal investment and alternate energy tax credits require certain prerequisites for property to qualify. Consultation with federal and local tax guides and/or authorities is advisable.

The 16% discount rate is the rate of return on an investment that can be expected by a farmer and can be compared with the internal rate of return projected by the life cycle cost analysis. The 16% rate was chosen to be above the interest rate available on low risk Federal Treasury notes. Figure II-6 illustrates the effects on the internal rate of return (IRR) and investment payback period of various wood fuel costs. The equity assumed is 100% of the capital investment; however, these outputs differ depending on the amount of equity, the loan period and the loan interest rate. Using the $8/ton wood fuel



WOOD COST SENSITIVITY ($18200 EQUITY)
FIGURE II-6

cost mentioned in Table II-5, the payback period for the capital cost outlay would be approximately 7.2 years with an internal rate of return (I.R.R.) of 20.25%. This is a marginal payoff period and rate of return. The economic feasiblity is diminished further by the likelyhood of a farmer taking out a loan for a major portion of the capital outlay.

If the wood fuel system cost and fuel escalation rates are correct, there is only a small possibility that an automated wood fuel brooding system could economically replace an existing propane fuel brooding system. A more realistic possibility is the selection of a automatic wood fuel system over an LP gas system to be installed in a new broiler house. This selection, however, has some risks as mentioned above.

Conclusions

Utilization of an automatically stoked wood-fired system will be more economical if multiple uses of the system can be found. Use of a centrally located boiler or furnace to heat multiple broiler houses will decrease capital cost outlay per house and increase overall system efficiency.

Because of the small-scale nature of an automatically stoked wood-fired system, the relative crudeness of the operation may require either a more refined fuel than is commonly available or a system that is less than fully automated. The availability of wood fuel processing and delivery systems is very important in the development of a totally automated small-scale operation. These restrictions and lack of performance data on small-scale wood fuel storage and handling systems like those in this report make further system testing and a change in wood fuel marketing a necessity for a reliable, working wood energy system.

REFERENCES

1. Riley, John G., "Development of a Small Institutional Heating Plant to Utilize Forest Residue Fuels," University of Maine, American Society of Agricultural Engineers Paper NA76-101, August 1976.

2. Smyth, D. A., Riley, J. G., "Storage and Feeding of Wood Chips for Fuel," University of Maine, American Society of Agricultural Engineers Paper 79-3514, December 1979.

3. Smyth, D. A., Riley, J. G., "Small-scale Space Heating with Wood-waste, Brush, and Logging Residue Fuels," University of Main, American Society of Agricultural Engineers Paper 70-1608, December 1979.

4. D. A. Smyth, 1979.

5. Ibid.

BIBLIOGRAPHY

Ames, Glen, "Wood Fuel Costs," presented at Wood Energy Economics, Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia, April 30, 1980, pp. 45-66.

Atkins, Dale, et. al, Georgia Poultry Industry Research, Final Report for Project A-2464, Georgia Institute of Technology, Engineering Experiment Station, TAL, Atlanta, GA, August 1980, pp. 4-24.

Clifton, David S., et. al., A Feasibility Study for Wood Energy Utilization in the Southeast, Georgia Institute of Technology, August 1979.

Levi, Michael P., et. al., Decisionmaker's Guide to Wood Fuel for Small Industrial Energy Users, Solar Energy Research Institute, February 1980.

Nolte, Bill, "Wood Energy Applications," Final Report, Georgia Poultry Industry Research, Engineering Experiment Station, Georgia Institute of Technology, August 1980.

Wood Energy Financing, Engineering Experiment Station, Georgia Institute ofTechnology, Atlanta, Georgia, November 5, 1980.

Case Studies in Wood Energy, Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia, November 5, 1980.

Riley, J. G. "Development of a Small Institutional Heating Plant to Utilize Forest Residue Fuels," University of Maine, Orono, Maine, August 1976, ASAE Paper NA76-101.

Riley, J. G., D. A. Smyth, "Storage and Feeding of Wood Chips for Fuel," University of Maine, Orono, Maine, December 1979, ASAE Paper 79-3514.

Riley, J. G., D. A. Smyth, "Small Scale Space Heating with Wood-waste, Brush,and Logging Residue Fuels," University of Maine, Orono, Maine, December 1979, ASAE Paper 79-1608.

SECTION III

HEAT RECOVERY IN EGG PROCESSING PLANTS

by M.S. Smith

Introduction

In preparing whole fresh eggs for market, egg processing plants consume energy in the form of natural gas and electricity. Each time a process calls for heating or cooling of the product, a stream of wasted energy is exhausted to the atmosphere or pumped down a drain. But the energy in these streams can be reclaimed and reused by employing heat recovery technology.

Georgia Tech's Engineering Experiment Station conducted a research project to demonstrate the implementation of waste heat recovery technology in egg processing plants during the 1979 fiscal year. The Crystal Farms, Inc. egg processing plant in Chestnut Mountain, Georgia was chosen as the site for the demonstration. Using funds provided to Georgia Tech for poultry industry research by the Georgia Department of Agriculture, Tech engineers:

- Identified an economically recoverable waste heat stream
- Matched it to a process which could utilize the reclaimed energy
- Installed the heat recovery equipment
- Monitored its economic and technical performance

Identification of a Recoverable Waste Stream

A large percentage of the electrical consumption at the Crystal Farms plant is due to the roof mounted refrigeration units. Each of the five egg storage rooms in the plant is maintained between 50° and 60°F by two 10 horsepower units. Employing R-22 as a refrigerant, these units reject large quantities of heat into the environment which can be economically recovered.

Referring to Figure III-1, the refrigerant in vapor form at low pressure and temperature (point 1) is compressed to a higher pressure and temperature (point 2) by the electric motor-driven compressor. The superheated vapor flows to the condenser (a finned coil) where it cools down to saturation temperature (110°F) and condenses at constant pressure (250 psia) and temperature. This process liberates heat which is transferred by the coil to ambient air forced by a fan across the outside coil surface. The resulting high pressure liquid (point 3) flows across a specially designed valve which drops its pressure and temperature to lower values (point 4). The cold liquid refrigerant then receives heat from room air as it passes through the evaporator coil, and returns to the vapor phase (point 1), thus completing the cycle.

It is at the condenser where the majority of the heat is discharged to the atmosphere in the refrigeration cycle. Fortunately it is possible to recover the majority of this energy. Equipment is readily available that will transfer the heat normally lost to air, to a stream of water where it can in turn be used in product processing.

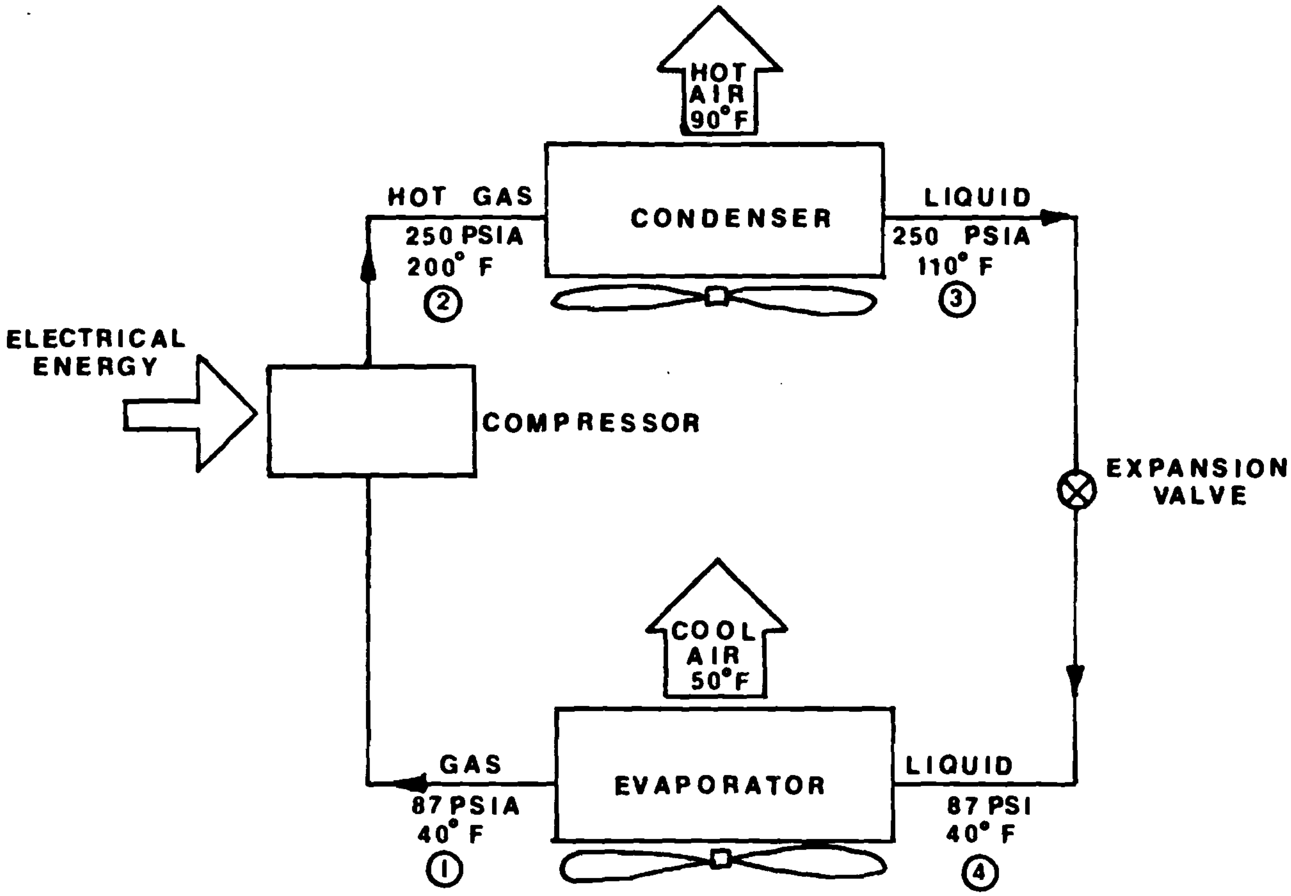


FIGURE III-1

TYPICAL REFRIGERATION CYCLE

Identification of Process to Utilize the Recovered Heat

By recovering the heat off the compressor of one of the plant's 10 h.p. refrigeration units, the temperature of incoming city water to the plant can be elevated to 110°F. For the recovery of this heat to be feasible, a use for it must be found in the plant.

An examination of the energy consumption patterns in the Crystal Farms plant revealed that water at approximately 110°F is needed at the egg washers. Natural gas is burned in four high temperature hot water heaters which supply domestic hot water, makeup water to the egg washers, and heat energy to the egg washer reservoirs.

The egg washers are part of the egg processing machines and they consist of rectangular covered tanks containing approximately 150 gallons of heated water-soap mixture. The water is pumped from the bottom of each tank and sprayed over the eggs which are transported through the unit by a conveyor belt. Since some water is lost by evaporation, continuous hot water make-up is required. In addition, the entire tank reservoir is discharged and refilled twice each operating shift in compliance with USDA regulations. To maintain the water-soap mixture in the tank at the desired 110°F, heat is required. It is supplied by circulating water from the heaters at 150°F through coils in the tank reservoir. The heating water is returned to the gas-fired heaters through a closed-loop pressurized piping system. By recovering the heat off the refrigerating compressor and sending it to the egg washer for use, a tremendous savings in natural gas consumption can be affected.

Installation of the Heat Recovery Equipment

Many systems are available for the recovery of refrigerant heat. Some cool the superheated refrigerant vapor (desuperheater) to the saturation point while others remove the latent heat of condensation as the refrigerant condenses as well. The unit selected for installation at Crystal Farms is manufactured by the Paul Mueller Company and can recover both the superheat and the latent heat of condensation from the hot gas stream.

The Mueller heat recovery system consists of two refrigerant-to-water heat exchangers, two 150 gallon insulated water storage tanks, and interconnecting plumbing. The heat exchangers are designed to cool (desuperheat) the hot refrigerant gas to saturation and then condense it (remove the latent heat of condensation). The heat exchangers are connected in parallel, each unit condensing half the total refrigerant flow. Thermal storage capacity is furnished by the water tanks. Flow from the tanks to the heat exchangers and back is induced by natural convection as depicted schematically by Figure III-2.

The heat recovery system was connected to one of the roof top refrigeration units between the compressor and condenser. Water heated in the actual exchange process was piped from the system storage tanks into the plant hot water heaters for use as preheated makeup water. Installation of the heat recovery system was accomplished by a local heating and plumbing contractor, H&R Mechanical Inc. of Gainesville, Georgia.

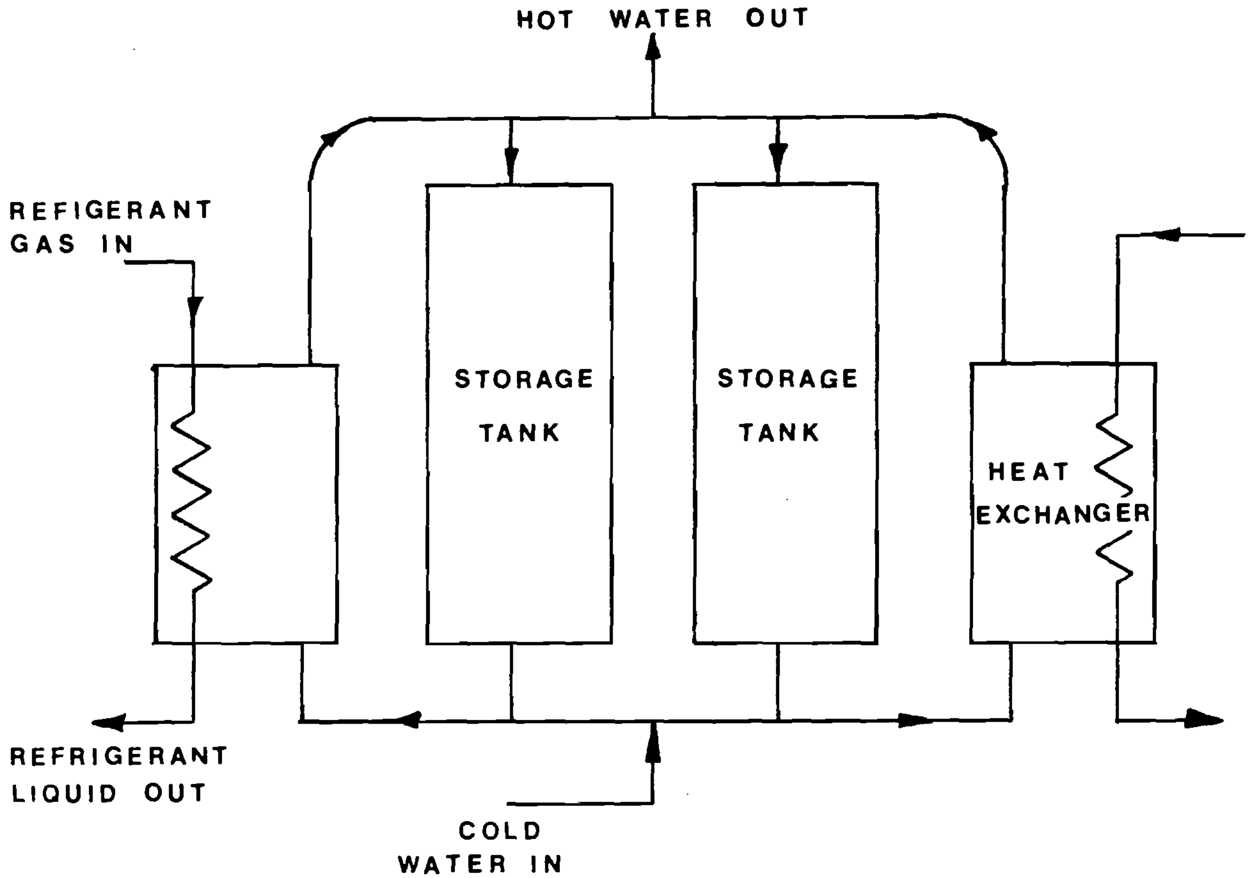


FIGURE III-2

HEAT RECOVERY SYSTEM

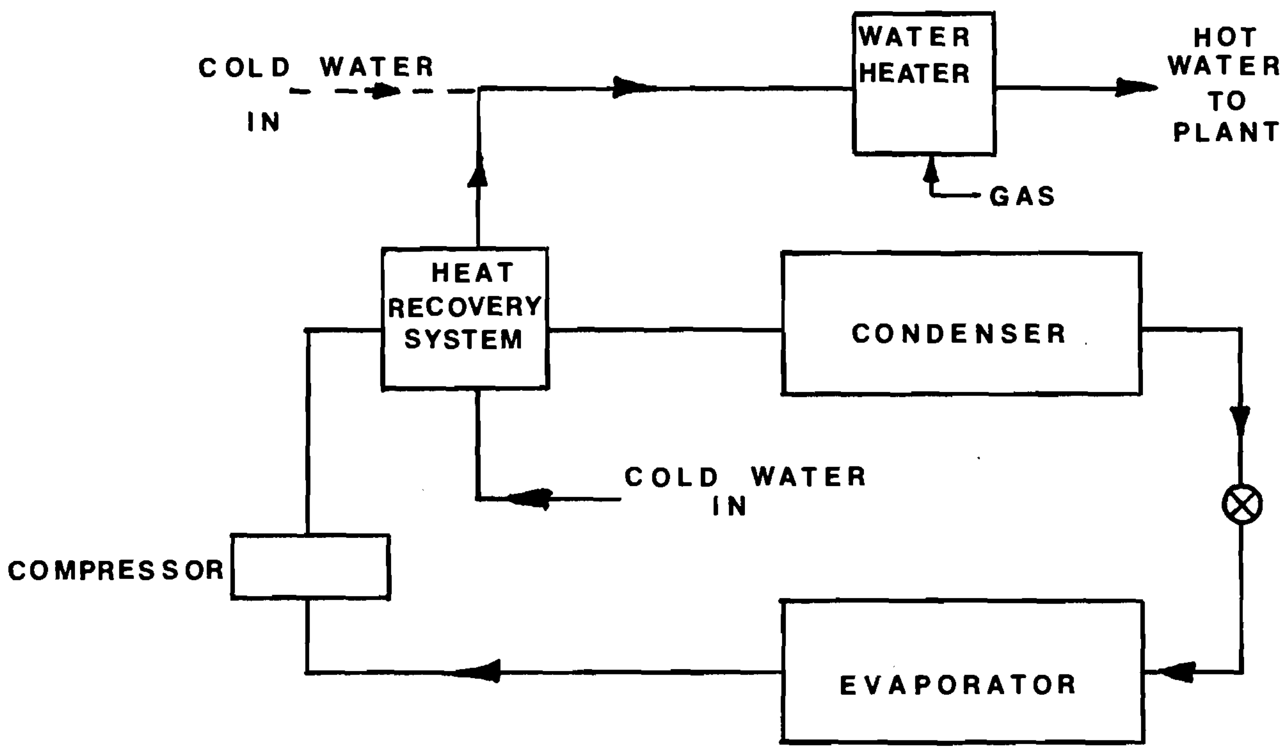
A schematic of the system is shown in Figure III-3 while Figure III-4 depicts the actual installation. When hot water is being drawn from the system, all refrigerant flow condenses in the heat exchanger and the existing condenser fans do not operate. However, when no hot water is required by the egg washers, a constant differential pressure valve installed in the refrigerant line diverts the flow away from the heat recovery system and it is entirely condensed by the existing fan cooled condenser.

System Performance

Upon initial startup in December 1979, the system was plagued with minor problems such as leaks in the water and refrigerant piping. Having repaired the leaks, it was decided to install the constant differential pressure valve described above in the hot gas line to divert the flow of refrigerant around the heat recovery system when there was no demand in the plant for hot water. Once the valve was in place, the system operated without incident for the next few months.

Recently, however, the refrigeration unit furnishing the hot R-22 to the heat exchanger has experienced a lot of down time. In an effort to restore the unit to normal operation, plant personnel replaced the compressor in January 1981. Unfortunately, this made little difference in the operation of the refrigeration unit or the heat recovery system.

Since the heat recovery equipment cannot function and provide hot water to be used in the plant unless the refrigeration unit is



HEAT RECOVERY SYSTEM INSTALLATION SCHEMATIC

FIGURE III-3

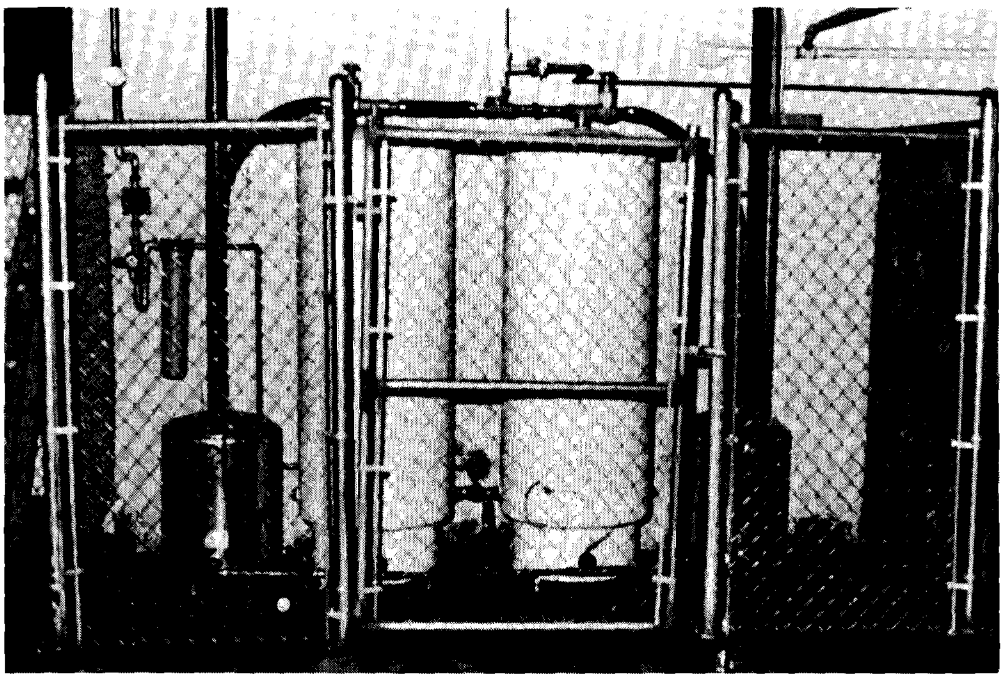


FIGURE III-4 HEAT RECOVERY SYSTEM INSTALLATION
AT CRYSTAL FARMS, INC.

operating satisfactorily, it is imperative that the problem be solved in a manner that will keep the unit on-line and functioning according to its design.

According to personnel at H&R Mechanical, the refrigeration unit is old and unpredictable. But even with replacement of the old compressor, no change was effected in the operation of the system. The contractor also suggested that the long runs of piping necessary to convey the refrigerant from the compressor to the heat exchanger and back again may be overworking the compressor causing it to malfunction.

This may well be the source of the problem. Pumping power is dissipated as a fluid is pushed through a piping system. The increase in fluid stream pressure provided by the pump (in this case the compressor) must be sufficient to move the fluid through the entire system while maintaining the operating conditions to which the thermal system was designed. This power dissipation or head loss is due to friction and is a function of the Reynolds number.

The Reynolds Number is a combination of four variables associated with the flow of a fluid through a pipe; the density, viscosity and velocity of the flowing fluid, and the diameter of the pipe through which it flows. For the case at hand the velocity, viscosity and density of the flow are well established and only the diameter of the pipe can be easily changed. If excessive pressure drop is found to be the cause of the problems experienced at the Crystal Farms plant, then the size of the refrigerant piping will be increased so that predicted performance levels can be realized.

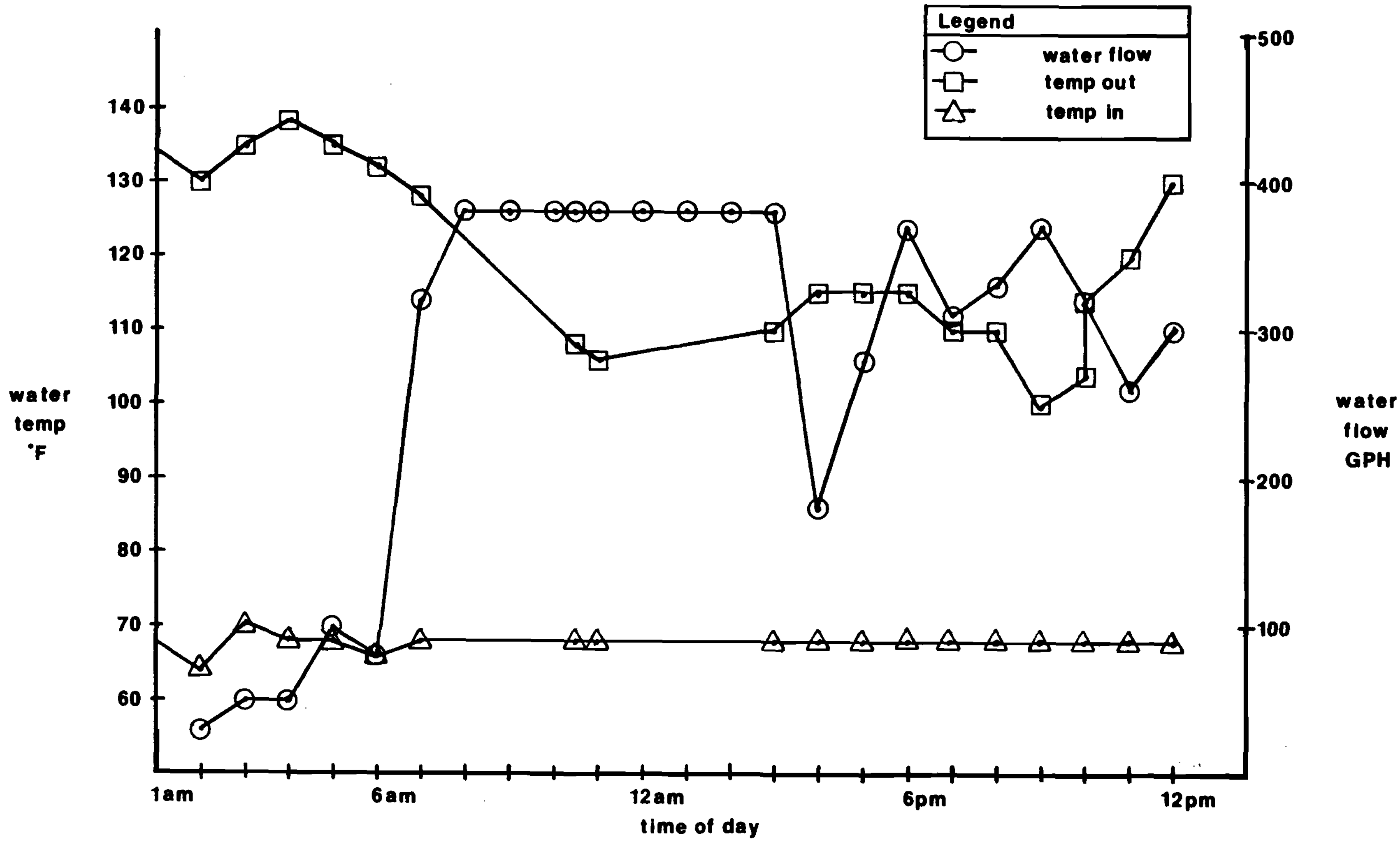
A check of the system will be conducted and data taken at all the refrigerant unit components so that a thorough analysis can be made. The information obtained will help pinpoint the cause of the system's malfunction as:

- excessive pressure drop in refrigerant piping runs;
- insufficient capacity of refrigeration unit to maintain egg storage room at 50°F and operate heat recovery system;
- blockage of refrigerant piping;
- refrigerant piping not capable of returning oil to compressor crankcase;
- faulty system controls.

Presently, the heat recovery system has been taken off line and plugged. The refrigeration unit is operating and appears to be effectively cooling the egg storage room.

The thermal performance of the Crystal Farms heat recovery system can be predicted by performing an energy balance on the system heat exchanger. If all external heat losses of the exchanger are neglected then the heat gained by the makeup water must equal the heat lost by the hot refrigerant. The heat gain by the water can be calculated from data on the water flow rate and the temperature rise of the water as it passes through the heat recovery system.

To accomplish this, thermometers were installed on the system water line together with an integrating water meter. Data gathered from the instrumentation was used to calculate heat recovery rates and to produce system performance curves, a typical example of which is shown in Figure III-5.



HEAT RECOVERY SYSTEMS PERFORMANCE

FIGURE III-5

The quantity of energy transferred by a heat exchanger to the fluid being heated is governed by the following equation:

$$Q = MCp\ (Tout - Tin) \qquad \text{(EQ 1)}$$

where:

Q = Heat recovery rate, Btu/hr
M = Water flow rate, lb/hr
Cp = Specific heat (water = 1 Btu/lb-°F)
Tout = Outlet temperature, °F
Tin = Inlet temperature, °F

Using this equation and the raw data, heat recovery rates ranging from 114,676 Btu/hr to 135,798 Btu/hr were calculated. The average rate based upon this operational data was 123,647 Btu/hr.

Analysis of the performance data yielded several observations worthy of comment. From Figure III-5, a direct relationship between flowrate and system outlet temperature is evident, i.e., higher flow causes lower temperature. This is to be expected with any heat exchanger where energy input (in this case hot refrigerant flow) remains constant. The water flow and temperature fluctuations are also seen to correspond with the plant operating shifts. Since production ceases overnight, the system storage tanks heat up to maximum temperature. When water flow demand resumes, beginning with the day shift, temperature initially decreases then varies around a lower temperature according to daily water usage rates.

Economic Analysis

Is the recovery of condensor heat to preheat plant make-up water an economically attractive alternative for egg processing plants? By analyzing the investment in such a system using the simple payback period approach, the length of time required for the potential monetary savings generated by the alternative to completely pay for itself may be determined.

The following analysis is based upon data actually observed during the research effort:

Average hourly energy savings: Q = 123,647 Btu/hr

Heating boiler efficiency: E = 75% (measured)

Gas conversion: C1 = 100,000 Btu/Therm; C2 = 100 cu. ft./Therm

(1000 Btu/cu. ft.)

Current plant gas cost: ¢ = 29.83 ¢/Therm

Plant operating schedule: 16 hrs/day, 240 days/yr

The yearly gas savings is,:

$$S = \frac{(Q \times 16 \text{ hrs/day} \times 240 \text{ days/year})}{(E \times C1)} = 6330.7 \text{ Therms/yr}$$

In terms of cubic feet, S equates to 633,072 cu ft/yr

The yearly cost savings, \$, is:

$$\$ = \frac{(6330.7 \text{ Therms/yr}) \times (¢)}{100} = 1888.45 \text{ \$/yr}$$

The simple payback period (not including taxes and tax credits) is presented in Table III-1.

Table III-1

Installed cost		\$ 4,504.00
Annual energy savings		1,888.45
Less:		
Maintenance cost	est.	100.00
Net Savings		\$ 1,788.45

Simple payback period: \$4,504.00/1,788.45 = 2.5 years

Conclusions

This research effort has graphically illustrated the importance of careful design in implementing heat recovery off of an existing refrigeration unit. Poor design practices will result not in energy savings but in increased maintenance expenditures and equipment down time. Every effort should be made to locate the heat recovery equipment in close proximity to the refrigerant compressor. This should eliminate unnecessarily long piping runs and excessively high pressure drops in the refrigerant line. As has been shown, a properly designed and installed system can shave a significant amount of cost off a plant's natural gas bill. In short, recovering waste heat from refrigeration units is an economically viable, technically simple means of conserving energy in egg processing plants.

The problems encountered by the Crystal Farms unit have hampered its performance, but are by no means insurmountable. Georgia Tech engineers are presently working with plant personnel and installers from H&R Mechanical Contractors Inc. to alleviate these setbacks and bring both the refrigeration unit and the heat recovery system back on line. This work should be completed by the fall of 1981.

Based upon this research effort, it is concluded that the potential for reducing the consumption of fossil fuels through refrigeration heat recovery exists, is economically attractive, and should be considered by all of Georgia's egg processing plants.

BIBLIOGRAPHY

Atkins, Dale, et. al, Georgia Poultry Industry Research, Final Report for Project A-2464, Georgia Institute of Technology, Engineering Experiment Station, TAL, Atlanta, Georgia, August 1980, pp. 115-132.

King, Guy R., Modern Refrigeration Practices, McGraw-Hill Book Company, New York, New York, 1971, pp. 120-154, 252-264.

Personal conservation with Mr. Harvey Rooks, President, H&R Mechanical, Inc.Gainesville, Georgia.

Personal conversation with Mr. Jack Timms, Plant Manager, Crystal Farms, Inc.,Chestnut Mountain, Georgia.

SECTION IV

HATCHERY HEAT RECOVERY

by M.S. Smith

Introduction

During fiscal year 1979, engineers at the Georgia Tech Engineering Experiment Station determined that poultry hatcheries presented an excellent opportunity for the application of heat recovery technology. Utilizing funds provided by the Georgia Department of Agriculture through the Georgia Poultry Federation, engineers of the Technology Applications Laboratory designed and installed an air-to-air heat recovery system in a Georgia hatchery. The Wayne Hatchery in Clermont, Georgia was selected to be the site for the demonstration because it best represented a typical Georgia plant.

The incubation operation in the hatchery exhausts warm, moist air at approximately 100°F and 75% relative humidity. This air cannot be directly recycled into the plant because it is contaminated by carbon dioxide, viruses, and other pollutants characteristic of life. But the heat available in the exhaust stream can be recovered in an air-to-air heat exchanger and the heat transferred to the fresh make-up air entering the setter room.

Presently, comfort heat is supplied to the setter room by two propane heaters suspended from the ceiling joists. These types of heaters are used throughout the plant to provide heat for worker comfort. By recapturing the heat that is being lost in the exhaust of the setter machines (incubators), the amount of fuel which must be burned in these heaters can be reduced.

Description of Site

Located 12 miles north of Gainesville, Georgia on highway 129, the Wayne Hatchery is situated in a rural setting. The building is a one story, concrete block structure with a flat "built-up" roof. Last year the hatchery produced over 17 million chicks, up 11% from its 1979 production level.

Twenty Chickmaster setters occupy the setter room. Located along one wall are eight model 66 machines. The opposite wall is covered by twelve Model 99 setters. Two of these exhaust directly to the outside. The exhaust of the other ten is captured by an exhaust extraction system and then conveyed out of the plant by the extraction blower.

It is these ten machines that will provide the hot air stream for the heat recovery system.

System Description

Heat Exchanger

There are approximately 200 cfm of exhaust air available from each setter. Since ten setters are to be utilized, 2000 cubic feet per minute of air at 100°F should be available for heat recovery.

Measurements made on the existing exhaust system bore this out as an average exhaust flow rate of 2000 cubic feet per minute was obtained using an Alnor Velometer.

In accordance with the recommendations outlined in the ASHRAE Handbook & Products Directory Equipment Volume,[1] an air-to-air heat exchanger utilizing a plate-type heat transfer element was specified to reclaim the heat from the setter exhaust air. The Z-Duct Model 75M4A6 heat exchanger was selected to effect the transfer. This unit was designed to operate at flow rates up to 5000 cubic feet per minute with a nominal rating of 4000 cubic feet per minute. Although the design exhaust flow rate was only 2000 cubic feet per minute, the eight Model 66 Chickmaster Setters could provide an additional 1200 cubic feet per minute of exhaust air to the heat exchanger. The heat recovery system was designed with the idea that this extra air would be ducted into the system at a later date. This simple modification would up the exhaust flow rate to 3200 cubic feet per minute; within the suggested operating range of the Z-Duct heat exchanger. On the fresh air side, a design flow rate of 4500 cubic feet per minute was utilized. This fell well within the suggested operating range of the Z-Duct unit.

According to efficiency curves published by the heat exchanger manufacturer, this unbalanced flow scheme which features a greater flow rate on the make-up air side will result in a higher recovery efficiency than a balanced one.

Inside the exchanger, the two air streams are separated by a continously formed and folded aluminum sheet. The plate is folded accordian style so that the amount of surface available for the transfer of heat is dramatically increased. The surface area is further increased by conical dimples which have been formed in the plate to give it added rigidity. Because the heat transfer element is a continuous sheet with its ends sealed in a non-toxic refractory cement, cross contamination between the exhaust and make-up air is virtually zero. The transfer of heat is accomplished on primary heat transfer surfaces. No secondary surfaces, such as fins, are utilized. This makes the recovery efficiency independent of the element's design. Easy cleaning of the element is facilitated by the two access doors on each side of the unit.

One special consideration of this heat recovery application is the potential to recover the latent heat from the exhaust stream. By condensing the water vapor contained in the setter exhaust, the hatchery heat recovery system can take advantage of both sensible and latent heat transfer. Sensible heat transfer actually increases or decreases the temperature of the exhaust air, whereas the removal of latent heat converts the water vapor contained in the exhaust air to a liquid (i.e. condensing). No change in temperature occurs in the exhaust stream as a result of the transfer of latent heat, but energy is released by the condensing vapor.

A drain is furnished with the unit for the easy removal of the condensed water.

Duct System

Conveying of the various air streams to and from the heat exchanger is accomplished by two fans and their associated ductwork. One of the fans serves as the extraction blower and sucks the setter exhaust into the extraction duct system. The other fan is located on the plant roof in an existing evaporative cooler. This fan gathers makeup air from the outside and blows it down into the heat exchanger. The fan can supply up to 4500 cfm of makeup air to the heat exchanger.

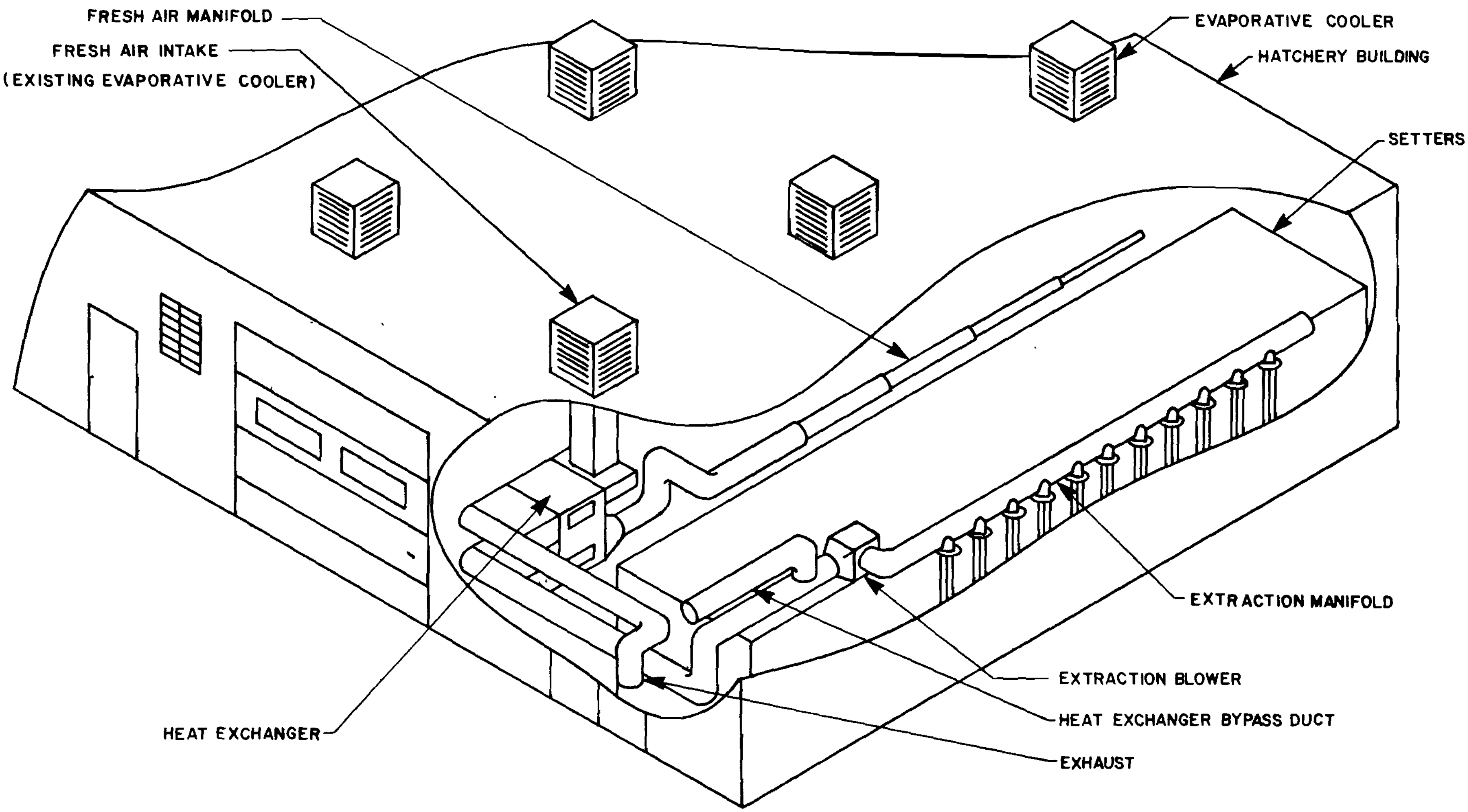
Manufactured by the Lockwood Company, the Model 130S extraction blower is equipped with a two horsepower motor and rotates at a speed of 1202 rpm at a static pressure of 2 inches of water.

The entire air distribution system has been designed in accordance with the recommendations and procedures outlined in the ASHRAE Handbook of Fundamentals[2] and the Manual for Recommended Practice of Industrial Ventilation.[3] All ductwork is steel sheet and except for the custom pieces is prefabricated snap-lock circular duct.

Figure IV-1 illustrates the location of all the key elements of the heat recovery system in relation to the hatchery building.

Air Flow Pattern in the Setter Room

Setter room air is drawn into the header section of the setter through a grill opening above the door. Here the air is conditioned so that the correct environmental conditions for setting can be maintained. To properly set eggs the air must remain within a quarter



HATCHERY HEAT RECOVERY SYSTEM

FIGURE IV-1

of a degree of 99.5°F. The amount of moisture in the air is also critical and is controlled by limiting the wet bulb temperature to a range between 85° and 95°F. After the air is conditioned, four fans force it down through the trays of eggs. Upon reaching the bottom of the setter, the air moves toward the rear and is drawn into the exterior exhaust stack.

As the contaminated air exits the top of the setter exhaust stack, it is sucked into the exhaust extraction system. The extraction system consists of a manifold duct fitted with ten hooded intakes - one for each setter. An air gap of 1 to 3 inches, between the top of the setter exhaust stack and the capture hood, serves to prevent the extraction system from influencing the flow of air through the setter.

Traveling up the intake duct, the air reaches the extraction manifold where it mixes with the exhaust collected upstream. The extraction blower then conveys the contaminated exhaust over to the heat exchanger. Once inside the heat recovery unit, the exhaust stream gives up its heat. The spent exhaust stream then blows into the exhaust duct work where it is channeled outside.

Makeup air is supplied to the setter room after it is captured off the roof and warmed by flowing through the heat exchanger. This fresh air is then distributed to the setter room by the supply ductwork. Running along the top of the Model 99 setters, the supply duct allows air to escape into the room through circular outlets cut into its side. Each of these outlets is fitted with an adjustable damper so that the flow may be regulated and the entire system balanced. Conventional circular ceiling diffusers are fitted over the dampers to evenly distribute the air into the room.

Energy Usage at the Wayne Hatchery

Due to its location, the Wayne Hatchery in Clermont is unable to obtain natural gas for use as an energy source. Consequently, propane is burned to provide the energy necessary to maintain worker comfort and to heat the water used in the tray washing operation. The balance of the plant's energy demand is handled by electricity.

During 1980 the hatchery produced over 17 million chicks. For each million chicks that were processed, 222 million BTU were consumed. This resulted in a total energy expenditure in excess of $37,500.00.

Although propane is used for space heating, the majority of the energy consumed by the plant is electrical. Therefore, as production has increased so has the amount of electricy consumed. In 1980, 72% of the total energy usage of the Clermont plant was electrical. Over 2.75 billion BTU of electricity were consumed. Up 5% from 1979 levels, the cost of electrical energy rose from $10.52 per million BTU to its peak of $11.71 per million BTU during the fourth quarter. Consumption increased during the first quarter of 1981, but the price per million BTU fell slightly to $11.14.

The price of propane also rose in 1980. While consumption was up 13.7% from 1979 levels, a 17% rise in propane costs was also experienced. The cost per million BTU jumped from $6.29 in the first quarter of 1980 to $7.38 by the end of the year. Propane costs increased to $7.52 in the first quarter of 1981.

Even though the primary objective of the setter heat recovery system was to cut propane consumption, it was hoped that electrical consumption would also be curtailed because air at a higher temperature would be available at the setter grill openings. This higher air temperature would require less energy supplied by the electrical resistance heaters (internal to the setters) in order to maintain the desired 99.5°F temperature.

Heat Transfer Analysis

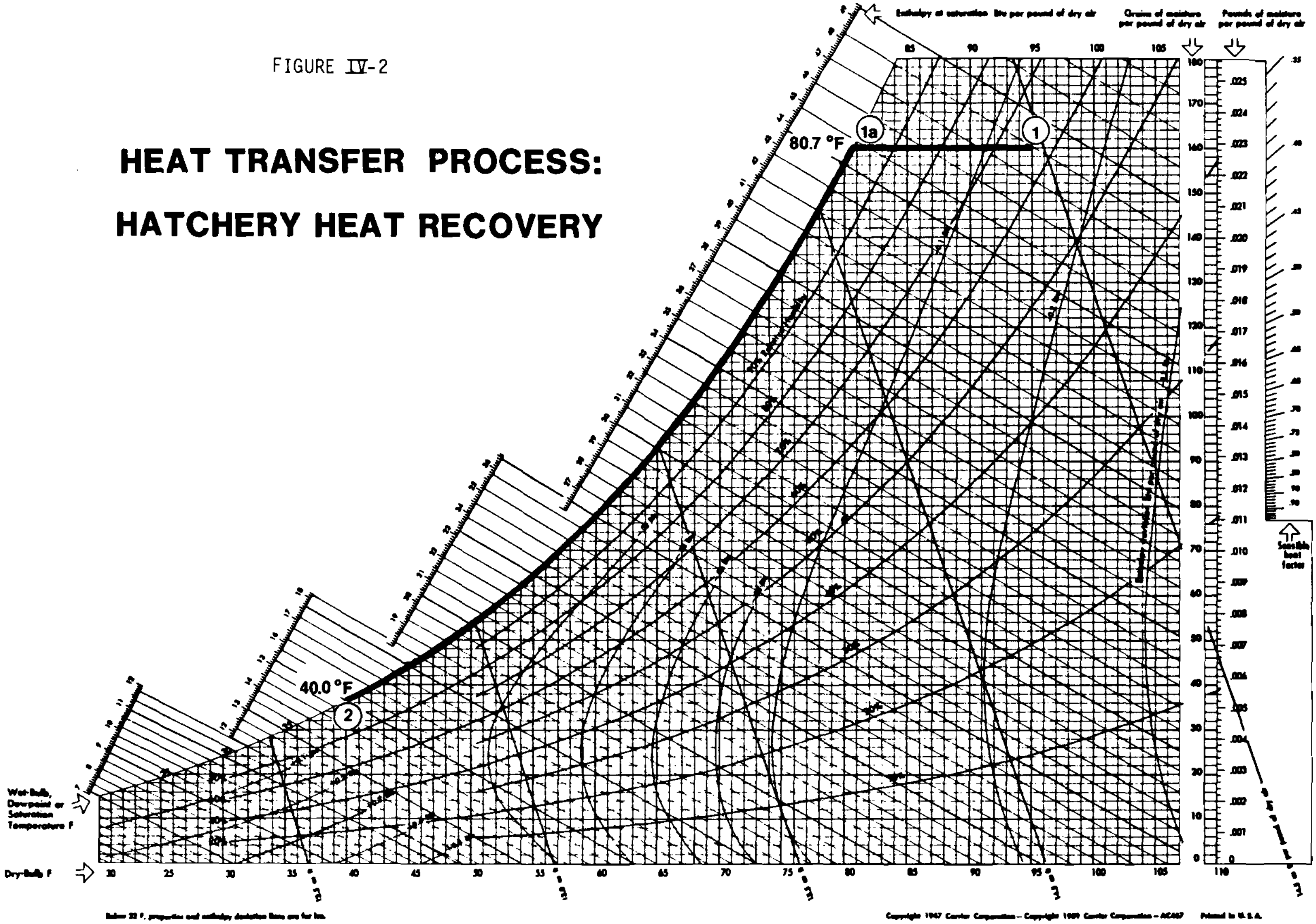
The process of recovering sensible and latent heat from a moist air stream is illustrated on the psychrometric chart in Figure IV-2. From the initial condition described by point 1, the air is cooled until it reaches its saturation temperature at point 1A. Here the water vapor begins to condense until the air stream reaches its final temperature at point 2. Point 1 corresponds to the condition of the exhaust air entering the heat exchanger and point 2 represents a thermal description of the exhaust air as it exits the unit. Point 2 is assumed to describe the air in a saturated or moisture laden state.

The amount of heat recovered, q, in taking the air from point 1 to point 2 may be calculated with the following equation:

$$q = m_a \left[(h_1 - h_2) - (W_1 - W_2)\, h_{w2}\right] \qquad \text{(EQ 1)}$$

FIGURE IV-2

HEAT TRANSFER PROCESS: HATCHERY HEAT RECOVERY



where:

q= heat recovery rate in BTUs per hour
m_a = mass flow rate of air in lbs per hour
h_1 = enthalpy of airstream at point 1
h_2 = enthalpy of airstream at point 2
W_1 = humidity ratio at point 1
W_2 = humidity ratio at point 2
hw_2 = enthalpy of condensed water at point 2.

Assuming a temperature at point 1 of 95°F and at point 2 of 40°F, the expected heat recovery rate was calculated at be 29.0 x 10^4 BTU/hr.

By performing a mass balance on the heat exchanger, it was possible to predict the amount of water that would be removed in the heat transfer process:

$$m_a W_1 = m_a W_2 + M_w$$

where:

M_w = mass flow rate of water in lbs per hour.

Using a mass flow rate, m_a, of 8866 lb per hour, the amount of water to be removed, M_w, was expected to be 2.6 lb per hour.

Data Aquisition

It was decided to monitor the exhaust air side of the heat exchanger in detail so that the amount of latent heat gain in the heat recovery process could be quantified. The dry-bulb temperature at each of the entrance and exit ports of the heat exchanger was monitored by an Omega copper constant (Type T) thermocouple. These readings were recorded every three hours by an Esterline Angus Model

PD-2064 programmable data logger. The dewpoint temperature of state 1 was monitored by a General Eastern Model 655 dewpoint transmitter. This was also recorded by the PD-2064.

Equipment was purchased to monitor the exhaust flow rate. A Dwyer Pilot Tube was inserted into the 14" circular exhaust duct and was connected to a Setra Systems Model 239E differential pressure cell. Unfortunately this equipment did not function satisfactorily, and the recorded data was of no use. Therefore the exhaust flow rate had to be determined by taking manual traverses of the duct as recommended in the Manual for Recommended Practice of Industrial Ventilation.[4] Once the velocity pressure measurements were taken, the velocity of the air stream was found from the following equation:

$$V = 1096.2\sqrt{VP/\rho} \qquad \text{(EQ 2)}$$

where:

V = velocity in feet per minute
VP = velocity pressure in inches of water
ρ = density of exhaust stream in lbs per cubic foot.

Multiplying the calculated velocity by the cross sectional area of the duct gave the flow rate through the pipe.

Numerous traverses were performed throughout the heating season yielding an average exhaust flowrate of 1646 cubic feet per minute.

Actual data was taken from January to April of this year. The average amount of heat supplied to the setter room over this period was 91,200 BTU per hour. This translates into a total of 197 million BTU for the first quarter of the 1981 calendar year. An average supply air temperature of 78°F was maintained.

Economic Considerations

It is imperative that energy conserving equipment save dollars as well as energy. The money saved by decreasing the consumption of a fuel source must be weighed against the money needed to purchase, install, and operate the equipment. Methods such as present worth or annual equivalent lend themselves to the comparison of alternatives, but there is no comparison of energy conserving options to be made in this case. Therefore the attractiveness of investing in hatchery setter heat recovery will be determined by calculating the simple payback period. Defined as the number of years it takes the savings generated from implementation of an option to completely pay for itself, the simple payback period is the quotient of the capital invested divided by the gross yearly savings.

Estimation of Gross Yearly Savings

Data was recorded at the Clermont plant between January and April of 1981. This meant an estimation of the energy savings in the last quarter of the 1980 calendar year had to be made. Data obtained from the Wayne corporate engineering office indicated propane usage for the last quarter of 1979 was 2875 gallons. During the same time period, the Clermont area logged 1170 degree days based on 65°F.

By utilizing the formula recommended in the ASHRAE System Volume[6] for estimating energy consumption based on the number of degree days, probable energy requirements for the last quarter of 1980 can be targeted. To predict the energy requirements use:

$$E = \frac{24\ H_L D}{\Delta T \eta (HV)} C_D C_F \qquad \text{(EQ 3)}$$

where:

E = fuel consumption for the estimation period
H_L = design heat loss (BTU/hr)
D = number of 65°F degree days for the estimate period
ΔT = design temperature difference (°F)
η = rated full load efficiency
HV = heating value of full source
C_D = correction factor for heating effect vs. degree days
C_F = interim part-load correction factor for fueled systems.

To determine the probable consumption for the final quarter of 1980, the ASHRAE equation was solved for E. For the quarter, 1353 degree days were experienced. Therefore, 3326 gallons of propane were necessary to provide the required heat energy, but actual consumption was only 2450 gallons. Subtracting these two figures yielded an estimated savings of 876 gallons of propane.

Both the first quarter of 1981 and the first quarter of 1980 experienced the same number of degree days,[7] so they should have required the same amount of propane for comfort heating. Actual heat transfer data and area weather information were combined with company propane consumption records to estimate a savings of 2650 gallons of propane during the first quarter of 1981. Combining this with the estimated savings from the fourth quarter of 1980 indicates a yearly savings of 3526 gallons of propane.

Delivery of the heated makeup air to the setter room is accomplished by one of the fans in an existing evaporative cooler. Since this fan would not be running during the heating season were it not for the heat recovery system, the cost of the electrical energy used to power the blower must be deducted from the dollar savings due to a reduction in propane demand. After subtracting out this electricity charge, the setter heat recovery system saved the Wayne Hatchery an estimated $2191.00 during the 1980-81 heating season.

The total capital invested in the purchasing and installation of the equipment was $7822. Division of this quantity by the estimated energy savings for the year resulted in a simple payback period of 3.6 years.

In calculating this payback period, the effect of taxes, tax credits, and depreciation have been ignored. An analysis which took these into account would result in a higher payback period due to the reduction in the annual energy savings. Table IV-1 shows a step-by-step breakdown of the economic analysis.

It should be pointed out that some savings would result from a decrease in electrical usage by the space heaters located in the setter room. Although fueled by propane, electricity is used to drive the fan which blows air over the heated coils. No effort was made to document this savings during the last heating season, but any savings realized should be credited to the setter heat recovery system. Next year will offer an opportunity to instrument these fans and quantify this savings.

Table IV-1

HATCHERY HEAT RECOVERY ECONOMICS

Capital Invested		
Heat Exchanger	$2392.00	
Drain Pipe	19.00	
Duct Work	1069.00	
Dampers	266.00	
Diffusers	100.00	
Insulation	100.00	
Miscellaneous	83.00	
Total Equipment Costs		$4029.00
Installation of Heat Exchanger and Associated Ductwork		$3793.00
Total Capital Invested		$7822.00
Gross Annual Energy Savings		
Propane Savings for 4th Quarter 1980	$ 587.00	
Electricity Required to Operate Heat Recovery System	115.00	
Net 4th Quarter Energy Savings	$ 472.00	
Propane Savings for 1st Quarter 1981	$1829.00	
Electricity Required to Operate Heat Recovery System	110.00	
Net 1st Quarter Energy Savings	$1719.00	
Total Energy Savings for 1980-81 Heating Season	$2191.00	

Simple Payback Period Based on Gross Annual Energy Savings, T:

T = $7822/$2191 per year = 3.6 years

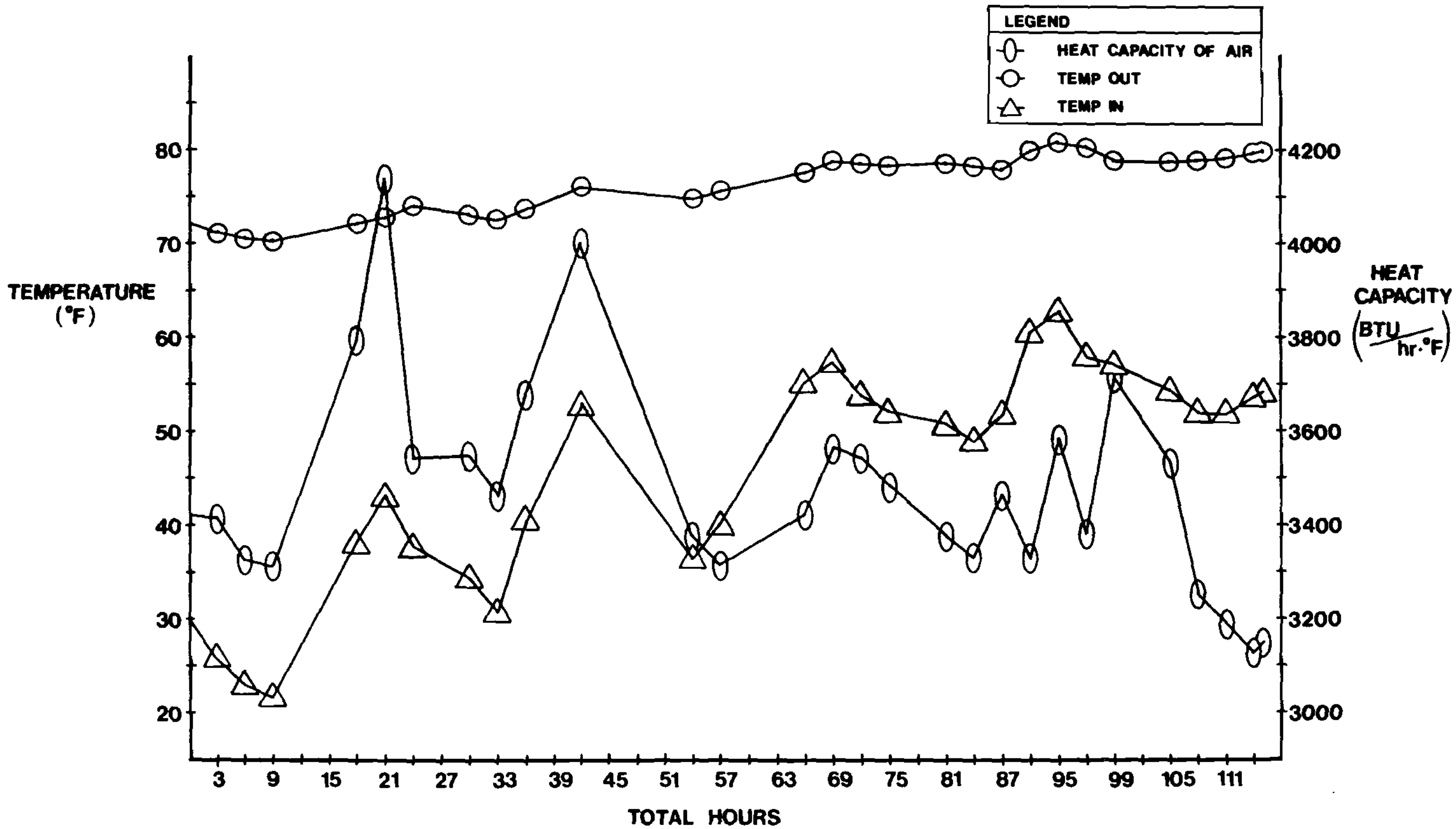
Results

The hatchery setter heat recovery demonstration project has shown that the technology and equipment is available to make the recovery of setter exhaust heat economically attractive. Depending on the amount of hot exhaust air made available to the heat exchanger, a very high percentage of the heat needed in the setter room for worker comfort could be furnished by the heat recovery system.

An average heat recovery rate of 91,200 BTU per hour was realized at the Clermont plant during the first quarter of 1981. The importance of the recovery of the latent heat in the exhaust stream is illustrated by the fact that latent heat recovery averaged 61% of the total recovered energy for each data frame recorded. Makeup air was supplied to the setter room at an average of 78°F. Figure IV-3 depicts system performance on the makeup air side for a typical data run. Estimated savings based on data collected during the past heating season totaled $2191, indicating that in 3.6 years this setter heat recovery system could pay for itself. These results support the recovery of setter exhaust heat by an air-to-air heat exchanger as an effective and efficient method of hatchery management.

Conclusions

Recovering heat from the exhaust streams of hatchery setters appears to be a viable means of reducing plant energy costs. A reduction in propane consumption of 34% for the 1980-81 heating season



HEAT RECOVERY SYSTEM PERFORMANCE; MAKEUP AIR STREAM

FIGURE IV-3

was realized over that of the previous year. The savings resulting from implementation of such a system could recover the invested capital in approximately 3.6 years.

In many hatchery operations, comfort heat is furnished by natural gas instead of propane. The economics of setter exhaust recovery is not as attractive for natural gas but deregulation of the natural gas industry could drastically alter the pricing picture for all gaseous fuels. Such a scenario would make the displacement of natural gas economically attractive and would make the displacement of propane a must.

Plans have been made to monitor the performance of the hatchery heat recovery system during the coming year. It is anticipated that next year's performance will be even better because the amount of exhaust air made available to the heat exchanger should be increased. A significant exhaust leak at the extraction blower outlet has been plugged and plant management has expressed the desire to pipe the eight model 66 Chickmaster setters into the system. Such a modification would be accomplished with Wayne Hatchery funds and would provide 1200 cubic feet per minute of additional hot air for heat recovery. Interfacing the extra setters with the present system would not be difficult because the existing design recognized the possibility of just such an increase in capacity. Plant personnel have already funded and installed a heat exchanger by-pass line which diverts the setter exhaust air away from the heat exchanger and carries it directly outside when there is no demand for heat in the setter room.

A more accurate determination of the heat recovery rate should be obtained once the malfunctions in the exhaust flow measurement system are corrected. Next year's data will be reduced on the Georgia Tech computer so more data points can be examined.

Exhaust air quality is a concern of Tech engineers. Is the performance of the heat exchanger adversely affected by the condensibles and contaminants in the exhaust air? Will the useful life of the unit be shortened because of them? An analysis will be made to help provide answers to these questions.

As the price of gaseous fuels continues to rise it becomes imperative to get the maximum usage out of every unit of fuel that is purchased. The recovery of the energy captured in the exhaust streams of hatchery setter machines is a painless way to improve a plant's effective usage of energy and more efficient usage will result in increased dollar savings in plant operation.

REFERENCES

1. ASHRAE Handbook, Equipment Volume, ASHRAE, New York, New York, 1979, pp. 34.1-34.18.

2. ASHRAE Handbook, "The Cooling of Moist Air," 1977 Handbook of Fundamentals, ASHRAE, New York, New York, 1978, pg. 5.8.

3. Committee of Industrial Ventilation, Industrial Ventilation, American Conference of Governmental Industrial Hygienists, 1978.

4. Ibid.

5. ASHRAE Handbook, "Modified Degree Day Procedure," Systems Volume, ASHRAE, New York, New York, 1976, pg. 43.8.

6. Ibid.

7. NOAA, Climatological Data, Georgia, National Oceanic and Atmospheric Administration, Vol. 83, No. 10-12, Vol. 84, No. 1-12, Vol. 85, No. 1-4.

BIBLIOGRAPHY

ASHRAE Handbook, "The Cooling of Moist Air," 1977 Handbook of Fundamentals, ASHRAE, New York, New York, 1978, pp. 5.8, 6.3-6.10.

ASHRAE Handbook, Psychrometric Tables, Handbook of Fundamentals, ASHRAE, New York, New York, 1977, pp. 6.1-6.9.

ASHRAE Handbook, "Modified Degree Day Procedure," Systems Volume, ASHRAE,New York, New York, 1976, pg. 43.8.

ASHRAE Handbook, Equipment Volume, ASHRAE, New York, New York, 1979, pp. 34.1-34.18.

Atkins, Dale, et. al, Georgia Poultry Industry Research, Final Report forProject A-2464, Georgia Institute of Technology, Engineering Experiment Station, TAL, Atlanta, Georgia, August 1980, pp. 133-140.

Carrier Corporation, Psychrometric Chart, Syracuse, New York, Copyright 1947,1959.

Committee of Industrial Ventilation, Industrial Ventilation, American Conference of Governmental Industrial Hygienists, 1978, pp. 6.1-6.42, 9.1-9.7.

NOAA, Climatological Data, Georgia, National Oceanic and Atmospheric Administration, Vol. 83, No. 10-12, Vol. 84, No. 1-12, Vol. 85, No. 1-4.

SECTION V

BROILER HOUSE ENERGY OPTIMIZATION

by C. C. Ross and M. S. Smith

Introduction

In 1980, approximately 574 million broilers were produced in Georgia using an estimated 2.24 trillion BTU in heating and electrical energy. Table V-1 illustrates the various types and utilization of fuels used in the Southeast Region in 1974[1]. Electrical energy use was estimated in the same survey to be on average 114.4 KWH per 1000 birds. Figure V-1 illustrates a general chart of energy use in broiler production in the United States.

These figures illustrate energy use regardless of house type and other important variables which can significantly affect energy consumption in broiler production.

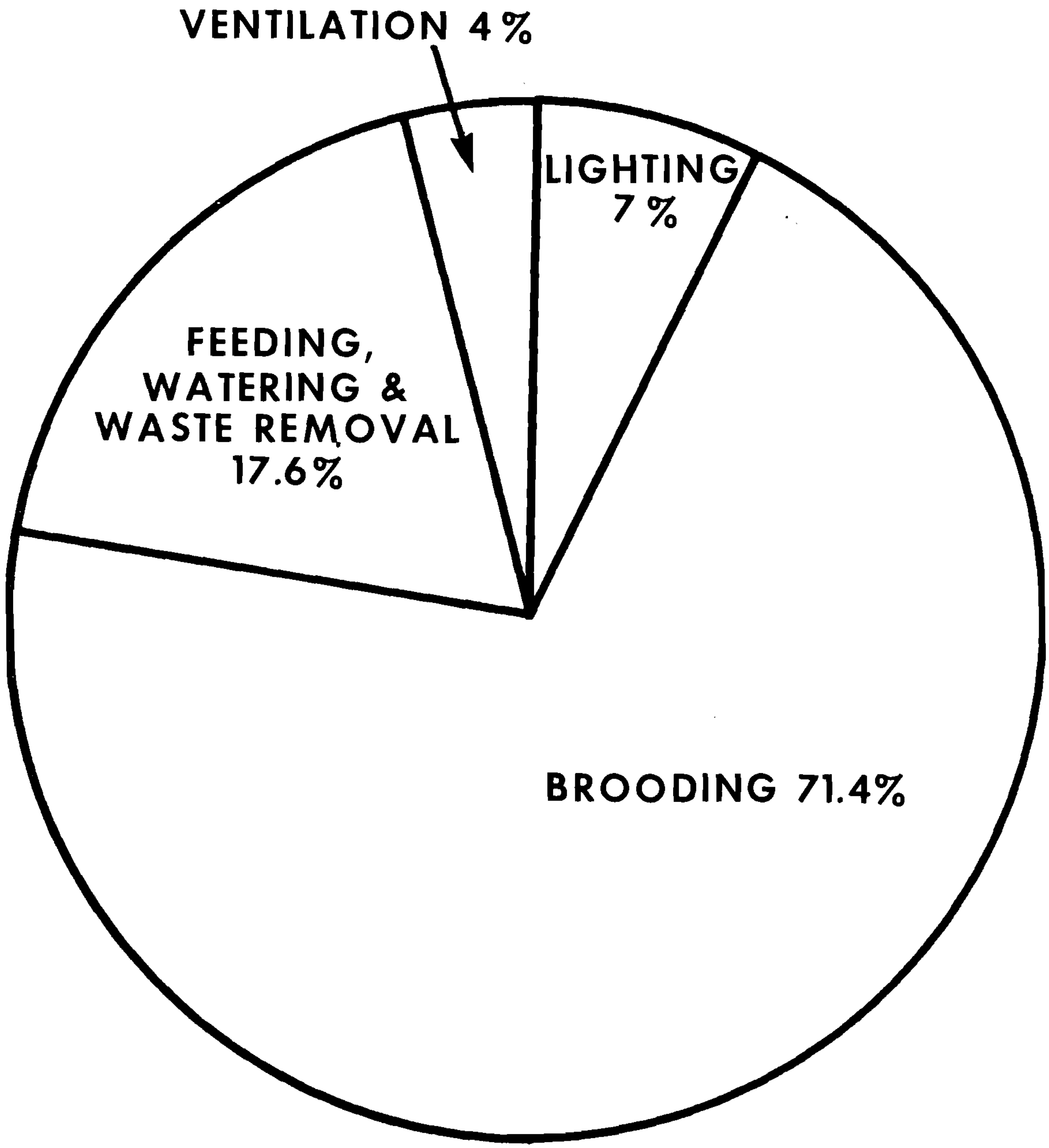
One of the more significant differences exists in the fuel and electrical energy use in environmental housing versus conventional curtain housing. As can be seen in Figure V-2, energy use varies between the two types of housing and between seasons.[2] Electrical use differs similarily because of the power ventilation and continuous lighting required in the environmental house. This is particularly so during the summer and is due to the use of natural ventilation in the conventional house. Fuel use differs because of the totally enclosed and insulated conditions of the environmental house in comparison to the conventional curtain house with no insulation.3

Table V-1

Proportion of and Average Fuel Usage in Broiler Production in Southeast*

	Type of Fuel Used				
	LP Gas	Natural Gas	Fuel Oil	Coal	Total
Average fuel use per 1000 birds	38.57 gal	15,397 ft^3	52.04 gal	0.37 tons	
Proportion of type of fuel used(%)	81.2	2.0	2.8	14.0	100.0

*Followup study in 1976-1977 indicated little variation in national and regional energy use patterns.



PERCENT OF THE BTU ENERGY USED IN U.S. POULTRY PRODUCTION

FIGURE V-1

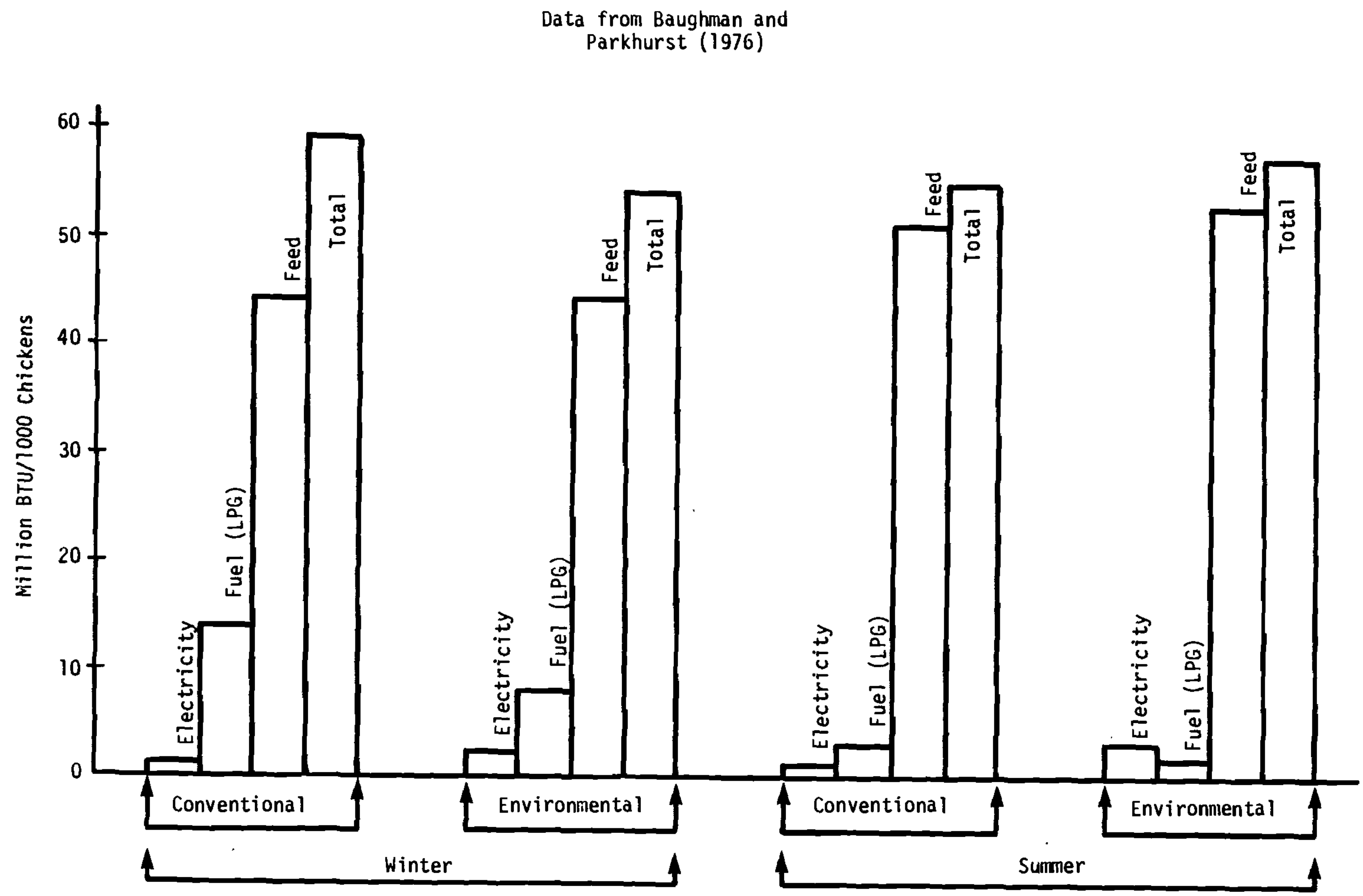


FIGURE V-2. Effect of Housing Type and Season on Energy Input for Growing Broiler Chickens

Figure V-2 also illustrates another consideration in broiler house energy accounting, namely feed energy. The total feed energy far overshadows the electrical and fuel energy inputs. This demonstrates the importance of broiler performance (i.e. feed conversion, bird weight and mortality) in energy management decisions.

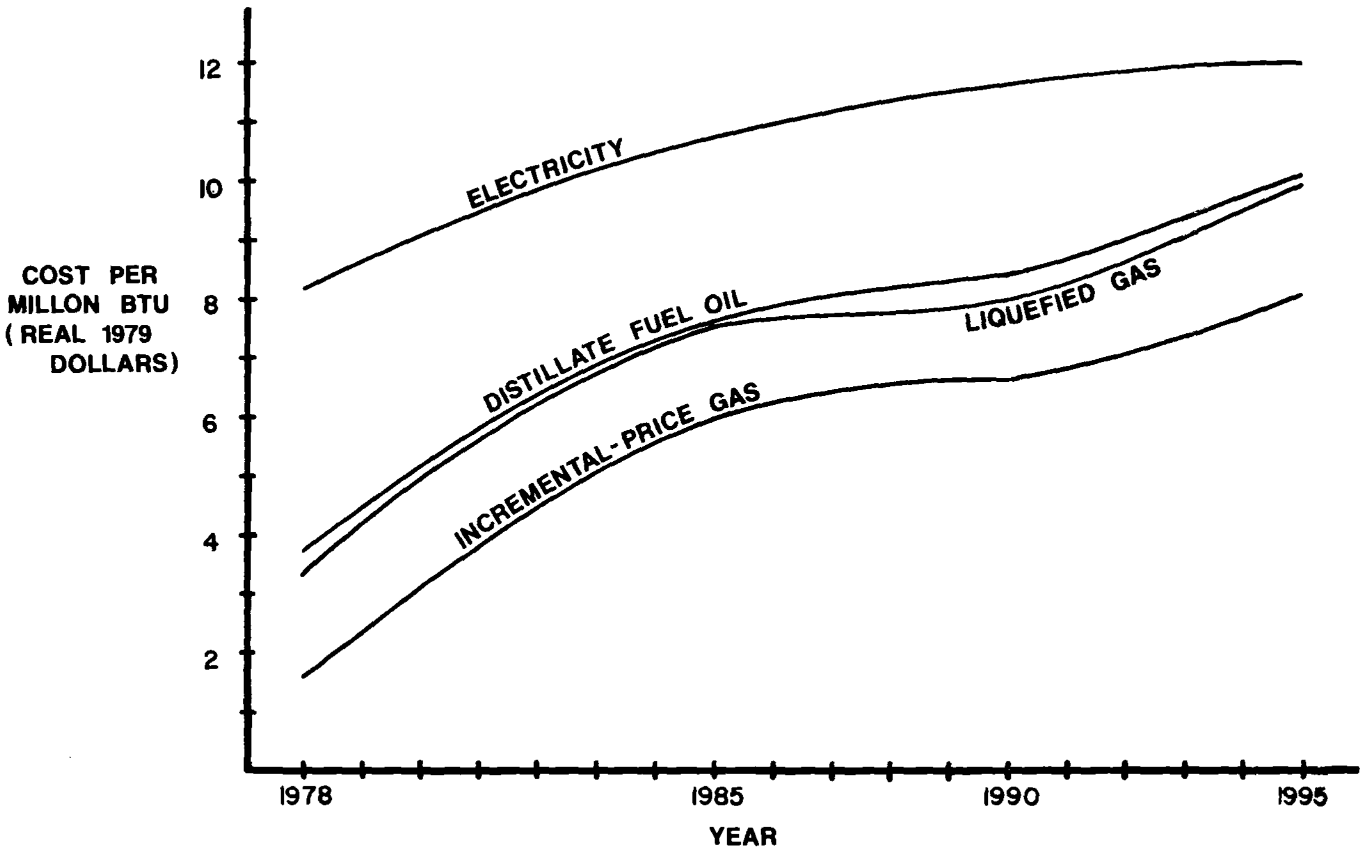
The bottom line, however, in balancing feed, fuel and electrical energy inputs may not be actual energy consumption, but actual cost per unit of energy consumed. Figure V-3 illustrates action 1978 prices projected future prices for various conventional fuels and electricity. The real dollar increases, which exclude the effects of inflation, are probably due to recent and future deregulation of the petroleum and natural gas industry among. This emphasizes a commonly held opinion that conventional fuels are going to escalate in cost above the general inflation rate and, in addition, possibly be subject to interruption.

Hence, the background is established for the development and installation of energy conserving and alternate energy technologies in the broiler industry. The purpose of this study is to evaluate past and present research in this field and develop a general plan of action for broiler housing in Georgia.

Energy Conservation Technologies

Brooding

Brooding energy, as seen in the introduction, is by far the largest segment of energy use in broiler production. This is because



PRICE PROJECTIONS FOR VARIOUS CONVENTIONAL ENERGY SOURCES

FIGURE V-3

maintenance of a "comfort zone" close to the changing thermoneutral temperature range of a broiler chick is very important for optimum bird performance. Figure V-4 illustrates the thermoneutral and recommended rearing temperature ranges for chickens.[4] Prevention of chilling and overheating during the first couple of weeks after placement is important in establishing long term performance of the broiler flock. It is important for this reason that energy is distributed properly in the brooding area, and that any change in that distribution from the use of energy conservation or alternate energy technologies maintain an adequate thermal climate.

Heat and Moisture Conditions

Environmental housing is an attempt to totally control the brooding environment. It has been successful in producing better broiler performance and reduced brooding fuel use.[5] However, this has been at the expense of higher electrical use for ventilation and lighting and higher construction and insulation costs.[6] In the Southeast, this is a dilemma when mild winters and hot summers provide a need for an environmental house for fuel conservation and a curtain house for natural light and ventilation.

Limited area brooding is an increasingly popular method of energy conservation. Depending on the type of house and management involved, different types of limited area brooding are utilized. The difference exists in how the house is used for brooding and in the scheduling and management techniques used therein. Using a barrier(s) to partition a part of the house, thereby increasing the stock density and reducing

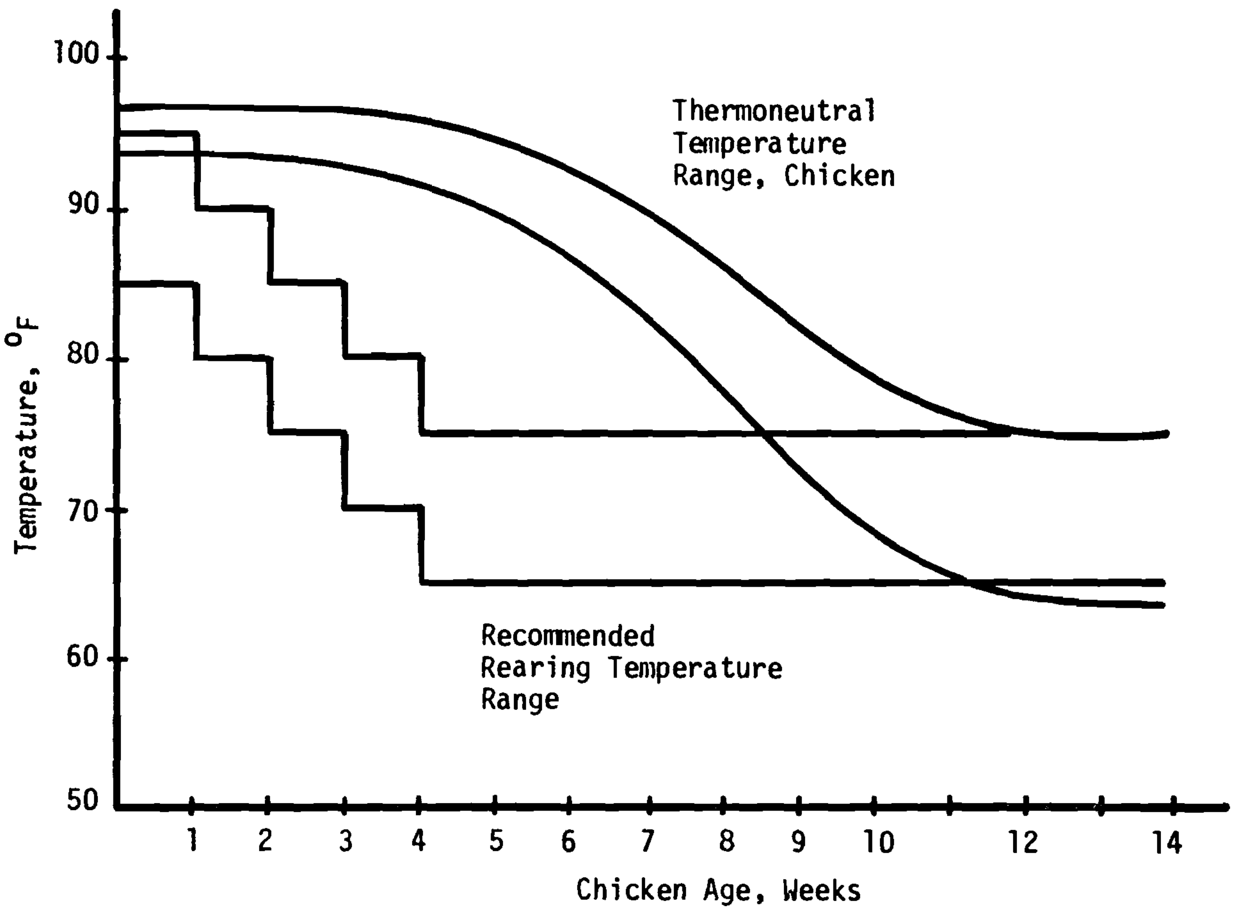


Figure V-4. Comparison of Thermoneutral Temperature Range With Recommended Rearing Temperature Range for Chickens.

the effective house volume, can reduce fuel consumption up to 40 percent.[7] This, however, is not without some drawbacks. Management becomes more critical due to the increased flock density. Changes in the normal lighting, ventilation, feeding and watering systems may be required to accommodate the increased density and reduced volume.

Most broiler brooding energy in Georgia is supplied by propane radiant brooders. Radiant heat is also supplied by natural gas or electric brooders. Convective heating through either ductwork or fan jet tubes is utilized by a few Georgia broiler operations.

Proper adjustment and maintenance of the brooding energy source can be helpful in reducing fuel consumption. One study found that either reducing brooder temperatures or adjusting brooder heights can conserve fuel without a reduction in broiler performance.[8] In environmental chamber tests, it was found that brooder temperatures could be reduced as low as 76.6°F the first week with no effect on broiler weight gain and feed conversion. Another study found that brooder effectiveness could be increased as much as 20 percent by operating it at its optimum height.[9] Fuel can be conserved because chick comfort needs can be met with less fuel at an optimum brooder height. This latter study also illustrated brooder pilot fuel consumption which ranged from 0.10 to 0.40 CFM per brooder for the brooders tested. Some of this fuel can be conserved by turning off a portion of the brooder as weather and flock age changes and the need for brooding heat subsides. There is also a possibility of using electric start pilots much like those used in commercial heating systems to further conserve pilot fuel.

Other energy conserving ideas include proper maintenance of water and feeding systems. Water spillage not only wastes water but also the energy required to evaporate it and remove it from the growout area. Maintenance of feeders and their electric motors can reduce the energy requirement for feeding.

Insulation

Weather conditions have been important factors in the growth of poultry production in the south. Somewhat mild winters and low fuel costs have in the past made insulation an unnecessary added expense. Recently, however, insulation has become a primary means of energy conservation in broiler housing in the face of spiralling energy costs. With this, several considerations need to be made concerning insulation of a broiler house:

- insulation requirements
- insulation costs
- animal contact
- fire resistance

Insulation requirements can be determined by analyzing the heat loss or gain from a broiler house. This will vary with several factors including weather conditions, housing type and broiler management. The heat loss or gain from a building can be determined from the simple equation:

$$Q = U_c A_t (ti - to) \qquad \text{(EQ 1)}$$

where:

Q = Total heat flow, BTU/hr.
U_c = Overall heat transfer coefficient, BTU/hr (ft^2) (°F)
A_T = Total area of walls and roof, ft^2
t_i = Inside air temperature, °F
t_o = Outside air temperature, °F

Weather conditions directly affect the heat flow to and from a broiler house by the change of the outside air temperature (to). The changes in wind conditions and the effects of solar radiation indirectly affect the value of Q by changing the coefficient of heat transfer(U_c). Because of this, insulation requirements can vary due to the differences in weather conditions across the country and even the state.

Housing type also is a primary variable in the calculation of broiler house heat loss or gain. Equation (1) somewhat eludes to this in that the total area of the walls and roof (A_T) can be altered by the geometry of the building. This can be elaborated further by looking at the calculation of the overall heat transfer coefficient, (U_c):

$$U_c = \frac{A_1\ U_1 + A_2\ U_2 + \ldots .A_n\ U_n}{A_1 + A_2 + \ldots\ldots A_n} \qquad \text{(EQ 2)}$$

where:

U_c = Overall coefficient of heat transmission, BTU/hr (ft^2) (°F)

A_1, A_2,...An = Areas in ft^2 of different sections of house

U_1, U_2,...Un = U values for different sections of house

The values of A_1, A_2,...An which represent different sections of a house (roof, sidewall, door, etc.) can change with the configuration of the building. Such changes include pitch and size of the roof and height of the sidewalls.

The values of U_1, U_2,...Un which correspond to these different house sections also vary with housing type. These U-values are determined by the various types of materials making up the house sections (roof, sidewalls, door, etc.) and their exposure to outside and inside conditions. They can be calculated from this equation:

$$U = \frac{1}{R_t} \qquad \text{(EQ 3)}$$

$$R_t = R_1 + R_2 + \ldots Rn \qquad \text{(EQ 4)}$$

where R_t is the total thermal resistance of the house section and R_1, R_2, etc. are the individual thermal resistances of the building materials, insulation and dead air spaces.

Table V-2 gives R-values for various types of insulation and other components found in poultry house construction.[10]

The effects of roof insulation not only include reduced fuel usage in the cool months, but also can mean reduced mortality in the summer months. At least one research effort found that roof insulation used in fan-ventilated sections of a typical broiler house reduced the maximum daily temperature 6 to 7°F and the average daily temperature 3 to 4°F.[11] Environmental chamber tests under high temperature and humidity conditions also found a 50 percent reduction in mortality by heat prostration of 7-week old male broilers in an insulated roof house.

Table V-2

Insulation R-Values of Various Materials[10]

Material	R-value - Per inch (approximate)	R-value - For thickness listed
Batt and blanket insulation		
Glass wool, mineral wool or fiberglass	3.50	
Fill-type insulation		
Cellulose	3.13-3.70	
Glass or mineral wool	2.50-3.00	
Vermiculite, expanded	2.20	
Shavings or sawdust	2.22	
Rigid insulation		
Expanded polystyrene, extruded, plain	4.00-5.26	
Expanded rubber	4.55	
Expanded polystyrene, molded beads	3.57	
Expanded polyurethane, aged	6.25	
Glass fiber	4.00	
Wood or can fiberboard	2.50	
Foamed-in-place insulation		
Expanded urethane, sprayed	6.25	
Urea-formaldehyde	4.20-5.50	
Building materials		
Concrete, solid	0.08	
Concrete block, 3 hole, 8"		1.11
Concrete block, lightweight agreegate, 8"		2.00
Concrete block, lightweight, holes filled with vermiculite		5.03
Lumber, fir and pine	1.25	
Metal siding		0.00
Metal siding, hollow-backed		0.61
Metal siding, insulated-backed, 3/8"		1.82
Plywood, 3/8"	1.25	0.47
Plywood, 1/2"	1.25	0.62
Hardboard, tempered, 1/3"	1.00	0.25
Particleboard, medium density	1.06	
Insulating sheathing, 25/32"		2.06
Gypsum or plasterboard, ½"		0.45
Wood siding, lapped, ½ x 8"		0.81
Windows (includes surface conditions)		
Single glazed		0.91
Single glazed with storm windows		2.00
Double pane insulating glass		1.72
Triple pane insulating glass		2.56
Doors (exterior)		
Wood siding, beveled, 3/4" x 10"		1.90
Metal, urethane core, 1 3/4"		5.26
Metal, polystyrene core, 1 3/4"		2.13
Floor perimeter (per ft. of exterior wall length)		
Concrete, without perimeter insulation		1.23
Concrete, with 2" x 24" perimeter insulation		2.22
Air space (3/4" to 4")		
Surface conditions		
Inside surface		0.68
Outside surface		0.17

The use of insulation in a broiler house can directly affect the amount of fuel used to heat the house by changing the R-value of a particular section. Because the roof has the largest area of the house, it is the most likely candidate for insulation and, over the years, most poultrymen have insulated their broiler house roofs to various degrees. However, increasing the R-value of only the roof and neglecting the sidewalls is not very effective use of insulation. Sidewalls, particularly those with curtain windows usually possess very low R values compared to roof R-values and therefore also need to be insulated.

Maximum benefits resulting from insulation of a broiler house can only be realized with good management conditions. Adequate control of heat and moisture levels through a good ventilation and heating system can not only directly affect the reduction of heat loss and heat gain through insulation, but also, help preserve the structural integrity of the insulating and building materials.

As mentioned earlier, sidewalls, because of the lack of insulation and high infiltration rates, are often the greatest source of heat loss in a broiler house. Environmental housing significantly reduces this problem by totally enclosing the sidewalls except for air inlets and fan slots, but increases other forms of energy use along with building cost. In order to take advantage of the natural ventilation and light conditions of a conventional house and the heat loss control of an environmental house, modifications of the present curtain wall housing can be made. Recent ideas include insulated window inserts, double curtains and insulated curtains.

Insulated window inserts could be used primarily during cool weather brooding periods where adequate ventilation for moisture removal and ammonia control can be provided without additional fans to those already in place. Framed bead board or other such rigid insulation could possibly be hinged to the outside of the curtain window. Provisions should be made for easy removal or placement by swinging an insulated insert up and away from the window. Such provisions should not interfere with normal window operation. Of course if partial house brooding is exercised, fewer panels are needed. Proper seal with this type of temporary set up is difficult, and the full insulating value of an insert may not be realized.

Figure V-5 illustrates a double curtain design. In addition to the insulating effect of two layers of curtain material instead of one, a thick dead air space with additional insulating value can be created when both curtains are completely closed. This air space has no insulating effect if the curtains are partially opened for ventilating air to pass through. It would be most effective during the early weeks of brooding when ventilation needs can be met with air slots and available fans and the curtains remain tightly closed. Some air control and perhaps pre-heating could possibly result from this type of configuration. Little data is available on this type of design at this time.

Figure V-6 illustrates the makeup of an insulated curtain designed by agricultural engineers at North Carolina State University.[12] The design, currently under patent application, uses

Figure V-5
Double Curtain Design

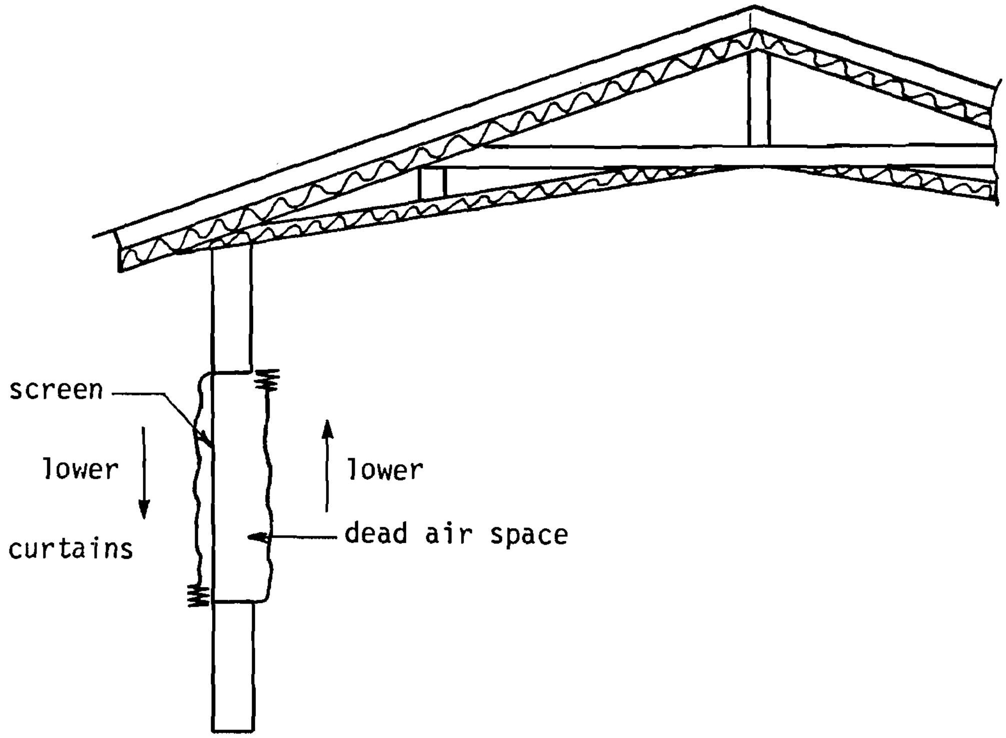
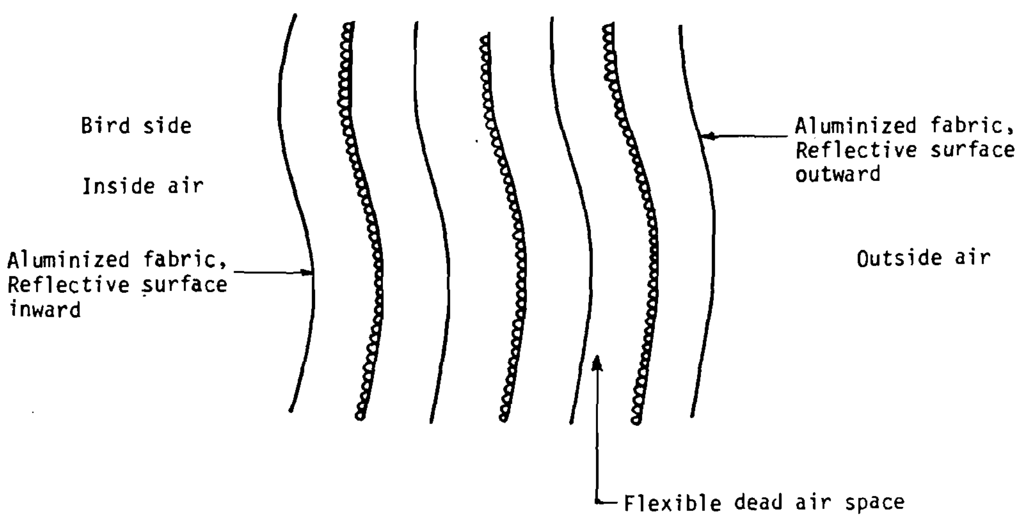


Figure V-6
Insulated Curtain



layers of material highly reflective to both high and low temperature radiation with layers of air pocketed material to provide conductive heat resistance in between. An ASTM guarded hot box test determined the R-value of the four layer curtain to be 5.7 (hr.) (°F) (ft^2)/BTU compared to a conventional translucent curtain material with an R-value of 1.0 (hr)(°F)(ft^2)/BTU. Researchers claim the curtain is durable enough for broiler house application. The R-value can be varied by the number of layers with the upper limit being the cost and bulkiness of the curtain. Tests in North Carolina have resulted in a 17% reduction in fuel use during brooding using an insulated curtain rather than a conventional curtain design. Other benefits include lower light levels with the insulated curtain; meaning reduced bird acitivity and better feed conversion.

The use of any of these techniques in brooding will save fuel, but, additional energy for daytime lighting, material costs, and ventilation requirements should be considered.

Since the cost of insulation is an important parameter, it is important to check not only the actual cost of insulation, but also, the cost of installing it. Some insulation may be less expensive, but it may also have higher installation costs and less structural strength and durability than other types.

Calculation of energy costs savings through insulation requires knowledge of the heat loss and load of the house during varying weather conditions and the cost and escalation rate of the brooding fuel used. The recent sharp increase in most brooding fuel costs has made the addition of insulation more economical. Consideration of the high escalation rate for brooding fuels should be made for present and future insulation installations. Even considering this, the actual cost of the brooding fuel may make some insulation installations uneconomical. Use of an alternate fuel such as wood or solar may be low enough in cost to prohibit extensive insulation or energy conservation measures.

Whenever insulation is installed, consideration should be made with regard to contact with the broilers and to the fire hazards associated with building materials. Most insulating materials, even those with a form of moisture protection, need a vapor barrier to discourage the deteriorating effects of the water vapor present in any animal contaminent shelter. Protection should also be provided for insulating material near bird level, either in the sidewalls, doors, endwalls or partial house separation sections to diminish the effects of bird contact. Care should be taken in determining the fire resistivity of insulation materials. Material suppliers and insurance companies can provide guidelines for appropriate insulation application.

Ventilation

During cold weather the primary objective of the ventilation system in a broiler growout house is the replenishment of the oxygen supply in the growout area. By refurbishing the house air periodically, control of the moisture and ammonia levels is affected. At other times its main function is the removal of excess heat.

Ventilation is divided into two categories: natural and mechanical. Natural ventilation is "powered" by natural forces such as pressure differentials and, to a lesser extent, differences in temperature across a building. Mechanical systems utilize fans and rely on electricity to move the required amount of air. Operation of a ventilating system requires careful grower attention and in the case of a mechanical system, the purchase of electrical power. Most of the growout operations in the State of Georgia use mechanical or a combination of natural and mechanical ventilation so an effective way to cut system power requirements and still maintain recommended ventilation rates would save many dollars in electrical costs.

Ventilation is far from an exact science. Table V-3 lists recommended ventilation rates for broilers as a function of outside temperature and straight-run body weight.[13] In the removal and replacing of air in a broiler growout house the amount of air flowing into the building per minute must equal the the amount flowing out per minute. Chances are that all other air properties will vary as the ventilating air flows through the house. Fluctuations in air velocity, temperature, relative humidity, and other psychrometric and transport properties can be expected. The engineering analysis involves predicting these properties in order to determine the amount of energy that is invested in the entering air stream and then lost as the air is exhausted to the outside.

The potential to save energy and money exists however, both in systems being planned for future installation and systems already in place and operating. Areas which offer potential savings are:

Table V-3

Age of Broilers and Roasters, Temperature and Ventilation Needs
(In Cubic Feed of Air per Minute per Bird)

Outside Air Temperature °F	Approximate Age of Broilers and Roasters, in Weeks						
	2.0	3.5	5.5	7.5	9.5	11.0	13.0
	Approximate Average Straight-run Body Weight, in Pounds						
	0.5	1.4	2.6	3.9	5.3	6.5	7.5
	Cubic Feet of Air per Minute per Bird						
40	0.24	0.7	1.2	1.9	2.5	3.1	3.6
50	0.30	0.8	1.6	2.3	3.2	3.9	4.5
60	0.36	1.0	1.9	2.8	3.8	4.7	5.4
70	0.42	1.2	2.2	3.3	4.5	5.5	6.3
80	0.48	1.3	2.5	3.7	5.1	6.2	7.2
90	0.54	1.5	2.8	4.2	5.7	7.0	8.1
100	0.60	1.7	3.1	4.7	6.4	7.8	9.0
110	0.66	1.8	3.4	5.1	7.0	8.6	9.9

- previous and current research projects
- better control systems
- better management practices involving the ventilation system
- proper maintenance of the installed system.

Each of these areas is discussed below.

Extensive research has been conducted in the area of ventilation for broiler growout houses. One study designed a broiler house which combined the advantages of windowless and curtain-wall housing.[14] Called the FLEX house after the management flexibility the design affords the grower, the ventilation system relies on both natural and mechanical phenomena to move the necessary air. The design calls for the curtain walled house to be fitted with an insulated curtain, a continuous roof ridge vent and slotted air inlets below the bottom of the curtain. The researchers suggest operating the building as a windowless structure during the day and running it like a conventional curtain-walled house at night. A savings of 19 million dollars in energy and feed costs is predicted by the researchers if every growout house in North Carolina were a FLEX House.

A few houses in the State of Georgia are employing fan jets and jet tubes to circulate ventilating air and prevent heat stratification. When the sidewall fans operate to exhaust air from the growout area, they also open vents in the end walls and the fan jets suck fresh air through these vents and blow it down the jet tube to distribute it through the house. If the sidewall fans are not running, the fan jets recirculate house air to maintain a breeze on the chicks and provide a uniform temperature throughout the house. These houses also utilize sidewall curtains so the ventilation system is a combination of natural and mechanical action. They may even employ a roof ridge vent if the ridge area is open to the growout area. Systems of this type have been employed in the swine, grain drying and greenhouse industries in the past, but more research is necessary to qualify and quantify their advantages for the broiler industry.

According to one research effort, savings in ventilation costs can be realized by including the contribution of natural ventilation and infiltration as part of the air required for moisture removal.[15] Unfortunately, there is no way to guarantee that the wind can furnish the forces necessary to remove moisture from the house, so some type of control system is required to inform the fans when they should operate and when natural ventilation can handle the ventilating load.

Even though they are somewhat unpredictable, natural forces should be exploited for their ventilating potential. By orienting the growout house to accept prevailing summertime breezes, some cooling of the house can be affected without the aid of electric power.

If the use of insulation in the poultry house requires the formation of an attic space, be sure to ventilate this area with suction cupolas or end vents. By flushing this area with fresh air, the temperature of the ceiling surface can be reduced and the birds will be more comfortable during the summer. The reverse is true during cold weather. To maintain a high ceiling temperature, ventilate the attic only for moisture control, if it becomes a problem.

The area in which the largest potential for dollar savings in ventilation systems exists is in their controls. Presently, ventilating fans are controlled by thermostats that monitor the house dry bulb temperature and by timers which insure that the fans operate enough to control odor and moisture. Since they are usually controlled by separate thermostats, it is quite possible that during the winter the ventilation system and the supplemental heating system may be operating at the same time.

An improvement in the control of poultry house ventilating systems has been proposed by F. N. Reece.[16,17] Instead of relying on the standard thermostat-timer control system a time proportioning controller is used to operate both the ventilating and supplemental heating systems. The controller generates a fixed length time cycle. A sensor determines the temperature, pressure, or some other physical variable and divides the generated time cycle proportionally into "on" and "off" time periods, with the ratio of on time to off time changing as the sensed variable changes. Each of the generated time cycles is divided into three time periods:

- Fan Operation - The ventilating system operates during the generated time cycle (between 0 and 5 minutes for the case reported).
- Neither Fan nor Heaters Operating - A delay between the time the fans stop and the heaters start provides a means of controlling house humidity levels.
- Heater Operation - Operation of the heater is indirectly controlled by the temperature in the building. The heating system will run, for each cycle, for 5 minutes minus the sum of the fan operating time and the delay time for the relative humidity control.

Such a system prevents simultaneous operation of ventilating and heating systems because both systems operate off of the same thermostat. Research is continuing in this area.

If a house is equipped with variable speed fans, most of them can be controlled to deliver as little as 10% of their rated capacity.

The control system is comprised of a solid state electronic speed control and a thermistor heat sensor. By altering the voltage supplied to the fan motor as the temperature fluctuates, the heat sensor changes the fan speed and therefore the fan capacity. Less power is used and the house is not overventilated.

In sidewall curtain houses it is possible to adjust the curtain height automatically. This continuous control capability represents an improvement over periodical manual adjustment. However, the cost of such a system and the power required to operate it may overshadow the amount of money which it could save.

Effective management of a ventilation system demands that the grower be intimately involved in its operation and maintenance. As the weather changes, the grower must adjust the inlets that regulate air flow into the space. The control doors on the air inlet vents must be repositioned according to outside conditions and the curtain height adjusted accordingly. Special care must be taken to prevent cold drafts from striking the chicks during cold weather. In the summertime inlets should be adjusted for maximum flow to achieve the necessary cooling effect on the birds.

It is important not to overventilate during the heating season. Check the ventilation rates recommended by the integrator for this time of the year and adhere to them. Unnecessary ventilation not only increases costs to operate the fans but also throws away heated air before full advantage can be received from it.

Fans should be selected on the basis of optimum efficiency for the conditions under which they will operate. In selecting a fan, look for those that bear the Air Movement and Control Association (AMCA) seal. AMCA fan ratings and performance charts guarantee a fan will deliver the specified cfm capacity for the static pressure and with the accessories in place as listed in the certification. This allows the grower to determine the capability of the fan to fulfill his needs because the fan has been tested under conditions similar to those under which it must operate. Next check the CFM per watt ratings at the pressure under which the fan will be used as well as at either 0.10 or 0.125 of an inch of water. Remember; the ratings should be specified with whatever accessory equipment is intended to be used on the fan. The addition of shutters and safety guards decreases the fan's free area and can rapidly reduce its air moving capabilities.

Proper maintenance, especially in existing buildings, is essential to saving money in ventilating systems. To minimize the energy required to operate a ventilation system, the following points should be considered:

- Shutters, fan blades, and air inlets should be kept free of dust and dirt. Check slot air inlets at least twice a year for blockage due to debris and dust accumulation. On fan blades dirt accumulation causes turbulence which causes the fan to work harder thereby lowering its air moving efficiency. Dust and dirt can work their way between the hinge pin and hinge bearings on fan shutters causing excess friction which makes the shutter blades more difficult to move. This places an extra load on the fan motor, thereby decreasing fan efficiency. Shutters should be cleaned once a month.

- Dirt and dust degrade thermostat performance. Keep them clean. A dirty thermostat can not sense temperature changes accurately or rapidly.

- Dust accumulation on fan motors acts as an insulating blanket causing them to overheat and eventually burn out. Clean them at least three times a year.

- Once a fan assembly is clean, make sure all moving parts are properly lubricated. Use a dry film lubricant or graphite on shutters as oil will tend to collect dust and dirt.

- Some ventilation fans are not equipped with sealed bearings and require lubrication periodically. Follow the manufacturer's guidelines being careful not to overlubricate.

- Check gable and soffit air inlets once a year for blockage. A 1/2 inch mesh hardware cloth is recommended for keeping out birds and rodents.

- In systems utilizing a jet tube or other ducting for distribution of ventilating air, periodically check the duct work for dust accumulation and clean as necessary.

- Periodically check belts for proper tightness. Rubber V-belts gradually stretch with use causing slippage between the motor and the fan. Do not overtighten belts, however, since this will severely overload the bearings. The belt is properly tightened when there is approximately 1/4 inch of play at the midpoint of the belt.

Many areas discussed here such as the FLEX house and time proportioning control systems exhibit the potential to save money but must still be termed experimental. Much research in the area of ventilation is being conducted at this time and practices accepted as standards today are subject to change in the near future. The changing economic conditions that broiler growout farmers face today will dictate to what extent today's research will be integrated into tomorrow's farm operation. Effective management and proper maintenance of existing ventilation systems are a must. Proper attention to the system's operation means money in the bank for Georgia's broiler farmers today.

<u>Lighting</u>

One reason reduced feed intake and increased weight gain has been attributed to windowless broiler housing is the use of continuous lighting programs. In a study by Deaton and Reece illustrating the effects of various lighting programs on broilers, continuous lighting at a level of 12.9 lux produced better feed conversion and body weight results over other lighting schemes.[18] Work by Carr has shown a 63% decrease in continuous lighting electrical energy use of a windowless house from using fluorescent tube lighting over incandescent.[19] Comparable results may be realized with conventional curtain houses utilizing available daylight with a night light management program using fluorescent instead of incandescent lighting.

Use of fluorescent lighting saves energy but also has some drawbacks. Initial fixture and lamp costs are higher than that for incandescent, but fewer fixtures are required with fluorescent for the same amount of light.

Dimming controls for fluorescent lights are currently expensive, but recent advances may produce a reasonably low cost dimming control as versatile as those available for incandescent. Other problems that may appear from long term use include high moisture and temperature effects on light performance. However, as seen in Table V-4, fluorescent tube life is much longer than incandescent.[20] This, coupled with reduced energy costs make fluorescent lighting an acceptable method of broiler house energy conservation.

To further conserve energy and money, a lighting program should be properly designed to provide uniform and adequate illumination levels. Table V-5 illustrates recommended light levels for various poultry tasks.[21] At least one study found light levels of 12.9 lux or below sufficient to maintain low levels of bird activity.[22] Illumination levels of 3-5 lux are needed by a human eye to note feeder and water levels. Proper spacing and light level specification should be used to provide only the illumination that is required. Proper lighting maintenance is necessary to maintain long lamp life and adequate performance. Dusty, moist conditions such as those found in broiler house can reduce lighting efficiency and life up to 50%.

Location

A site for the growout farm should be selected that will not only minimize the grower's labor input but will also minimize the amount of energy that must be purchased to operate it. Careful examination and thoughtful decisions about the prospective site before commencing construction could result in a significant savings over the useful life of the farm buildings. The location of trees, bushes, natural

Table V-4

LAMP DATA

Type of Lamp	Watts	Average Lamp Life (Hours)	Average Lumen Output
Incandescent	25	1,000	250
	40	1,000	450
	60	1,000	840
	75	1,000	1,150
	100	1,000	1,700
	150	1,000	2,700
Flourescent	15	20,000	660
	20	20,000	1,000
	40	20,000	3,200

Table V-5

RECOMMMENDED ILLUMINATION FOR POULTRY FARM INDUSTRY TASKS[1]

Areas and Visual Tasks	Minimum Illumination Levels (Lux)	Explanation
Feeding, inspection and cleaning	215.3	Provided by a lighting circuit separate from the circuit used to stimulate prod-tion and growth
Charts and records	222.9	Localized lighting is needed where charts and graphs are kept
Thermostats, thermometers and time	538.2	Localized lighting is needed to accurately determine readings or settings

[1] ASAE EP344, Lighting for Dairy Farms and the Poultry Industry

land formations, and other buildings will affect the extent to which natural phenomena such as prevailing winds and solar irradiation can be utilized in cutting energy costs.

Poultry growout houses should be located so that a natural windbreak such as evergreen trees or a bluff protects their north and west sides. During the winter months this will provide protection from the cold winter winds.

When possible locate the shelter on land with a 2-6% slope and open to prevailing summer winds. This facilitates drainage and aids in ventilating the structure during hot weather. Never build in a hole. Such an area can act as a heat sink and cause the local temperature to be higher than the surrounding countryside. An example of this is a large city in which the downtown temperature will normally be 3 to 5° higher than the temperature in the suburbs.

Orientation

Orienting the farm buildings in the proper direction is important in controlling solar heat gain and the effect of winds. Fixing the long axis of such buildings along an east-west line offers two distinct advantages:

- Such an orientation reduces the area for solar heat gain during summer afternoons while it exposes more surface area to the south during the winter months for the absorption of solar radiation.

- In the Southeast the prevailing wind in the summer is southerly so natural ventilation of curtain-type poultry houses is increased.

Another factor to consider is the amount of roof overhang. The proper relationship between the wall height of the building and the amount of roof overhang can provide shade to the interior of the building during the summer yet allow the warm rays of the sun to enter the shelter in the winter. Figure V-7 illustrates this relationship.[23]

Alternate Energy Technologies

Solar

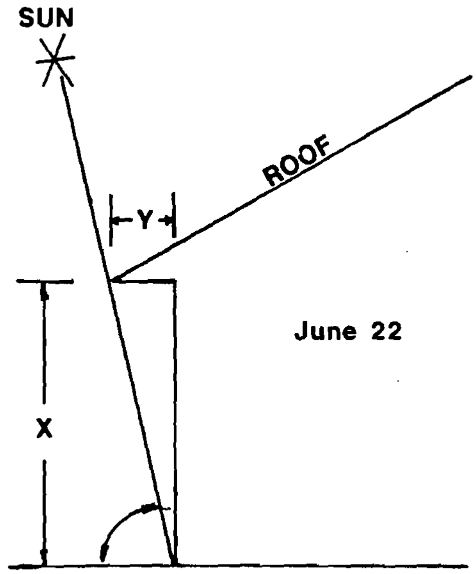
Various solar energy systems for poultry production have been tested over the years. Results have been mixed regarding the actual technical and economical feasibility of such systems in the Southeast.

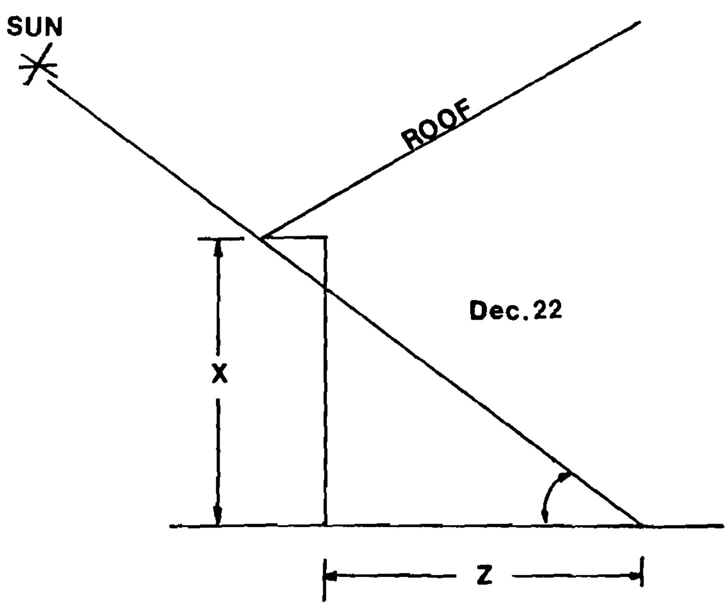
Auburn University has investigated the use of solar energy in poultry production since 1975.[24] Using environmental chambers, tests have been made on solar hot water brooding systems utilizing thermal storage and various convective heating systems including a heated concrete slab and finned tube convectors. The use of a hover over a finned tube convector resulted in a 49% displacement of the energy requirement in a January 1978 brooding trial. Other brooding periods had 90-100% of the energy needs supplied by solar. Other Auburn solar research includes an air-to-air solar collection system with rock

FIGURE V-7

SOLAR ALTITUDES IN GEORGIA

LOCATION	LATITUDE	JUNE ALT.	Y	DEC. ALT.	Z
No. Ga.	35°	78°	0.21x	31°	1.45x
Atlanta	34°	79°	0.19x	32°	1.41x
Mid Ga.	33°	79.5°	0.19x	32.5°	1.38x
So. Ga.	31°	81°	0.16x	35°	1.27x





X = wall height
Y = horizontal length of roof overhang
Z = horizontal distance sunlight will penetrate building

storage and a sidewall mounted, solar ventilation air preheater. Researchers concluded that because of the wide variation in energy needs under present brooding practices it is difficult to adequately size a solar system to provide maximum benefits for an economical cost.[25]

The U.S. Department of Agriculture Southeast and South Central Poultry Research Laboratories are also involved in solar energy research in poultry production. At the Southeastern Poultry Research Laboratory, tests have been made on utilization of a solar air-to-water collector with thermal storage with different heat transfer elements including a heated concrete floor, a finned tube convector and a water-to-air heating coil to heat incoming ventilating air. Most work has been on overall solar system efficiency, and total energy balances with the various heating elements.[26] Results indicate up to 75% of the required brooding energy in a well insulated environmental house can be met with the system.

Work is also being conducted at the South Central Poultry Research Laboratory with a hot water collector and thermal storage system in tandem with a ventilation air perheater. The ventilation intake air is heated through an air-to-air collector and passed through a convective radiator utilizing hot water from a solar air-to-water collector and thermal storage. In the winter of 1976-1977, a brooding trial indicated that 75% of an energy load equivalent to 35.66 gallons of LPG per 1000 chicks was met by the solar system.[27] Additional work with an air-to-air solar collector and rock storage system has shown comparable results with a simpler, less troublesome system.[28]

Since 1975, Georgia Tech has investigated the use of low temperature air-to-air solar collectors for use in broiler production.

Two solar heating demonstrations are currently in place in broiler growout houses. One utilizes a remote, passive rockbed solar collector. The other has an active, roof mounted, flat-plate solar collector. These systems are described in Section VII. Both systems were designed to be low cost and constructed on site. A number of design and material degradation problems have been encountered. Collector modifications have been undertaken at both sites to improve their performance. Performance monitoring is still underway. The active solar heating system with no storage has performed at an efficiency of 19-20% and has reduced house energy use by approximately 13.5%. Design changes and different materials could be utilized in an integrated design to solve some of the problems that have been encountered to date.

Wood

Since 1978, Georgia Tech has successfully demonstrated a wood-fired warm air brooding system. The main objective of the study was to reaquaint the broiler grower with an old fuel source and one of Georgia's most bountiful resources, wood. Technically, the system has performed without any major problems. The 350,000 BTU/hr furnace has supplied up to 95% of the brooding heat energy load with considerable savings in fuel and money (Section I).

Wood-Solar Energy Hybrid

To enhance the energy production characteristics of both the Georgia Tech designed solar roof collector and wood furnace system, a concept for integration of the two has been made as illustrated in Figure V-8. The primary objectives of this design is to:

- Integrate a simple, flat plate collector into the roof design of a broiler house.
- Utilize the same heat delivery ductwork to supply hot air from either/or both of the systems.
- Utilize the furnace system in lieu of thermal storage.

Use of the integrated roof design solar collector could provide a relatively inexpensive form of energy for day time loads. Glazing would be in the form of ultraviolet resistant corrugated fiberglass which would also serve as the roofing surface. The collector surface would be encased in the house attic space where insulation and collector support would already exist.

The ductwork would be used in the form of either a fan "jet-tube" to provide warm-air brooding or a rigid circular duct system with hovers for cold air brooding (Figure V-8). In-house controls would direct warm air from the solar collector either directly into the house or into the furnace heat exchanger as pre-heated air. Once the collector temperatures were too low to contribute an appreciable amount of energy, the whole system would rely totally on the wood furnace to satisfy the heating load.

Based on past Georgia Tech research, the solar collector could provide up to 13.5% of the heating load of the broiler house. Furnace

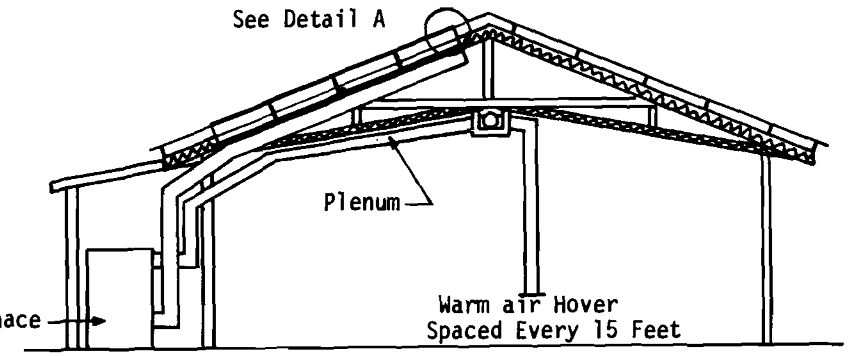
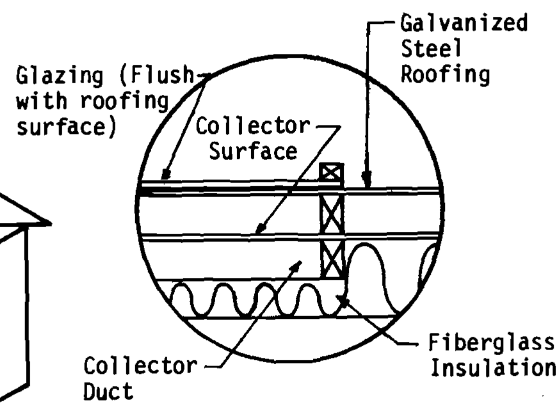


Figure 1A



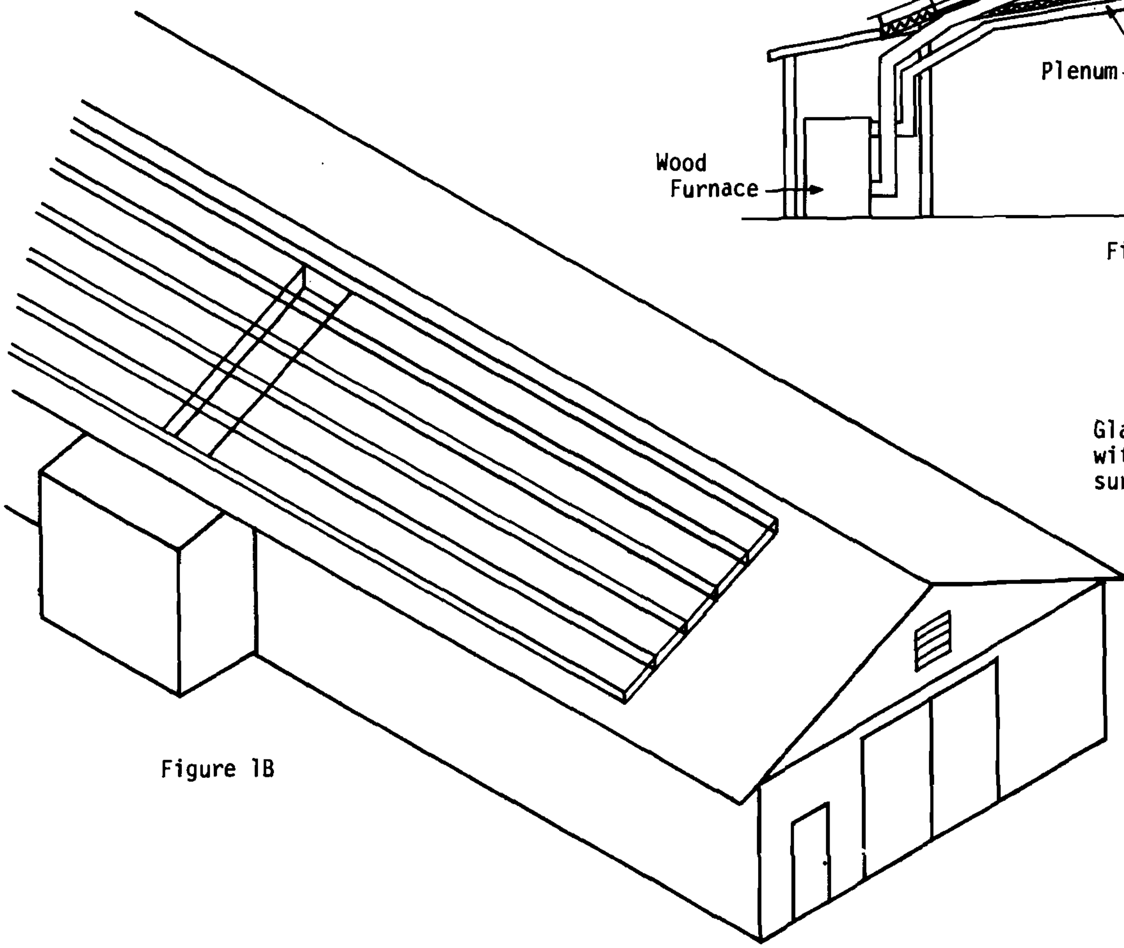


Figure 1B

Figure V-8
Wood-Solar Energy Hybrid

options for the remaining heating load would be either a furnace sized to handle the worst case cold weather conditions with week old chicks, or a smaller furnace like Georgia Tech's demonstration unit in Carrollton (Section I) with an adequate number of LP gas or natural gas brooders for supplemental or backup brooding heat.

Energy Optimization

As illustrated in the previous discussions, the variety of energy conservation and alternate energy technologies provide an infinite number of combinations to reduce or eliminate conventional fuel usage. The problem exists in that the results of such combinations are not always additive in their energy conserving or producing qualities. The addition of one technology to another could all but cancel the benefits each possess independently. Because this problem exists, optimization is necessary to attain the best performance out of available energy technologies.

The use of computer optimization has provided a method to analyze the myriad of environmental and technical parameters associated with broiler housing. USDA researchers at the South Central Poultry Research Laboratory have developed ten general mathmatical equations for poultry house ventilation, heating and structural design; to describe broiler heat and moisture production and environmental requirements; and to describe regional climatic conditions.[29] They can interrelate these equations with micro-computer programming to determine the effects of variations in temperature, ventilation rates, broiler growth and other important parameters. Optimum ventilation rates or insulation thicknesses can be found using this type of analysis.

Since 1976, researchers at the University of Delaware have been developing a model entitled "Systems Analysis of On-Farm Broiler Production".[30] The model is now used to determine fuel and electric costs, ventilation rates, economic thickness of insulation and the effects of brooding practices and window configuration on energy use. Resulting studies include "Economically Justified Insulation Thickness for Broiler Houses", a model used to determine economically justified broiler house insulation thicknesses based upon ownership, fuel and electric costs and projected inflation rates.[31] An analysis and rating system to evaluate broiler house energy conservation potential has been made for various Delmarva conditions.[32] The model was further developed by the recent addition of moisture and heat loss calculations dependent upon broiler growth rates.[33]

Other forms of energy optimization exist in various simulation models for heating, cooling and ventilation of residential and industrial buildings. An example of this type of simulation modeling being modified for agricultural use is found in a paper by Sumner.[34] A transient simulation program for solar heating and cooling of a residence is used to simulate the heating of a broiler house for development and sizing of various alternate energy production and storage components.

Other computer programs are available for economic optimization of energy related broiler house modifications. Two researchers used economic considerations to determine economically justified insulation thicknesses and energy conservation ratings in Delmarva broiler houses.[35,36]

One of the primary variables of an economic optimization analysis is the cost and escalation rate of the primary brooding energy source. LP gas and natural gas are the primary fuels in Georgia and the Southeast and both have risen in cost dramatically in the last few years. Recent decontrol of the petroleum industry and future decontrol of the natural gas industry will add an additional potential for escalation in brooding fuel rates. Because of this, many energy conservation measures are economically feasible in broiler housing. However, the costs and escalation rates for alternate energy sources will be different and could change the economic feasibility of the same conservation measures. This and other economic and technical variations illustrate the need for complete economic optimization through computer programming.

Conclusions

Although there has been an improvement in energy conservation in broiler production in Georgia, more work is needed to provide growers with alternatives to expensive conventional fuels. Use of technical, biological and economical factors should be made in the present and future optimization of broiler house energy use. Optimized use of energy conservation and alternate energy technologies could save millions of dollars in Georgia broiler production energy costs. It could also protect the broiler grower's small margin of profit from conventional fuel shortages and price fluctuations. Altogether, a program for development of energy conservation and alternate energy technologies would be useful for Georgia's broiler growers and consumers.

REFERENCES

1. Brewer, R.N., et al, "Fuel Use in Poultry Production," Poultry Science, 57: 363-364, 1978.

2. Data from G. R. Baughman and C. R. Parkhurst, North Carolina State University, Raleigh, 1976.

3. Ibid.

4. Ibid.

5. Braughman, G.R., Parkhurst, C.R., "Energy Consumption in Broiler Production," Transaction of the ASAE, St. Joseph, Michigan, Vol. 20, pp. 341-344, 1977,

6. Collins, N.E., et al, "Energy Conservation Standards for Broiler Houses," American Society of Agricultural Engineers, Paper 79-4578, St. Joseph, Michigan.

7. "Guide to Energy Savings for the Poultry Producer," USDA-FEA, 1977, Washington, D. C., pp.7-8.

8. Carr, L.E., Carter, T.A., "Fuel Savings by Reducing Broiler Brooding Temperatures," Transaction of the ASAE, St. Joseph, Michigan, Vol. 21, pp. 1189-1192, 1978.

9. Mattison, R., et al, "Energy Conservation in the Poultry Industry," Georgia Poultry Industry Research Final Report, Project A-2028, Georgia Institute of Technology, Atlanta, Georgia, 1978, pp. 41-53.

10. Doering, O.C., Moss, J.L., "Investing in Insulation for Farm Buildings," Energy Management in Agriculture, Series ID-145, 1980, Purdue University, West LaFayette, Indiana.

11. Reece, F.N. "Insulation and Energy Conservation in Poultry Houses," U.S.D.A.-ARS, South Central Poultry Research Laboratory, Mississippi State, Mississippi.

12. Timmons, M.M., et al, "Development and Evaluation of an Insulated Curtain for Poultry Houses", Journal Series of the North Carolina AgriculturalResearch Service, Raleigh, North Carolina, 1981, Paper No. 6688.

13. North, M. O., Commercial Chicken Production Manual, AVI Publishing Co. Inc., Westport, Connecticut, 1978, pg. 347.

14. Baughman, Parkhust, Timmons, "Reduced Mechanical Ventilation -The Poultry Flex House", Paper presented at the 1980 Winter Meeting of ASAE, Chicago, Ill., Dec. 1980, Paper No. 80-4510, 14 pgs.

15. Walpole, E.N., Collins, N.E., "The Effect of Infiltration on Broiler House Heating", Paper presented at the 1976 Winter Meeting of ASAE, Chicago, Ill., Dec. 1976, Paper No. 76-4532, 25 pgs.

16. Harwood & Reece, F.N., "Time-Porportioning Control of Livestock Structure Ventilation", Transactions of the ASAE, ASAE, St. Joseph, Michigan, Vol. 17, No. 4, 1974, pp. 714-716.

17. Reece, F. N., "A Dual-stage, Time-portioning Thermostat for Use in Poultry Houses", Poultry Science, Vol. 59, No. 2, Feb. 1980, pp. 231-233.

18. Deaton, J. W., Reece, F. N., "Effect of Varying Light Intensity on Broiler Performance," Poultry Science, Vol. 55, pp. 515-519, 1976.

19. Carr, L.E., "Lighting Systems Research," Proceedings of the 1980 National Broiler Housing Seminar, University of Delaware, Newark, Delaware, pp. 71-81.

20. Georgia Tech Engineering Experiment Station "Agricultural Energy Management Tips," Georgia Department of Agriculture, Atlanta, Ga., 1980, pp. 10.

21. "Lighting for Dairy Farms and the Dairy Industry," ASAE 1980 Agricultural Engineers Yearbook, ASAE Engineering Practice EP344, St. Joseph, Michigan, pp. 424-428.

22. Deaton, 1976.

23. Georgia Tech Engineering Experiment Station, "Agricultural Energy Management Tips", Georgia Department of Agriculture, Atlanta, Georgia, 1980, pp.5-6.

24. Flood, C.A., et al, "Brooding Chicken with Solar Energy," Presented at the 1980 ASAE National Energy Symposium, St. Joseph, Michigan, pp. 223-227.

25. Ibid.

26. Drvry, L.N., et al, "Solar Poultry Brooding Research at the Southeast Poultry Research Center," Presented at the 1980 ASAE National Energy Symposium, St. Joseph, Michigan, pp. 228-235.

27. Reece, F.N., "Use of Solar Energy in Poultry Production," Poultry Science, Vol. 60, No. 5, May 1981, pp. 911-916.

28. Reece F.N., Use of Solar Energy in Poultry Production," Presented at the 1980 ASAE National Energy Symposium, St. Joseph, Michigan, pp. 236-241.

29. Reece, F.N., Lott, B.D., "Optimizing Poultry House Design for Broiler Chickens," USDA-SEA-AR, South Central Poultry Research Laboratory, Mississippi State, Mississippi.

30. Walpole, E.W., Collins, N.E., "Simulation Modeling to Design Broiler Houses," ASAE Paper 76-5542, St. Joseph, Michigan, 1976.

31. Collins, N.E., et al, "Economically Justified Insulation Thicknesses for Broiler Houses," ASAE Paper 78-4554, St. Joseph, Michigan, 1978.

32. Collins, N.E., et al, "Energy Conservation Standards for Broiler Houses," ASAE Paper 79-4578, St. Joseph, Michigan, 1979.

33. Walpole, E.W., Collins, N.E., "Predicting Heat and Moisture Production by Broilers," ASAE Paper 80-4509, St. Joseph, Michigan, 1980.

34. Sumner, P.E., McLendon, B.D., "Simulation of an Energy Management System," ASAE Paper 81-4035, St. Joseph, Michigan, 1981.

35. Collins, 1978.

36. Collins, 1979.

SECTION VI

ENERGY CONSERVATION IN THE POULTRY PROCESSING INDUSTRY

by R.S. Combes, H.Z. Jackson & M.S. Smith

Introduction

In 1977 the Georgia Tech Engineering Experiment Station received funding from the U.S. Energy Research and Development Administration (now the Department of Energy) to demonstrate the impact of an extensive energy conservation program on the energy usage patterns at the Gold Kist, Inc. processing plant located in Ellijay, Georgia.

One of the conservation measures that was implemented during this demonstration project was the installation of an ammonia desuperheater to extract heat from the hot ammonia refrigerant and transfer it to the scalder makeup water. The installation is illustrated in Figures VI-1 and VI-2. Since processing occurs sixteen hours a day, five days a week, there is no demand for heated makeup water at the scalder during the other eight hours or during the entire weekend. However, the refrigeration system runs continuously so there is heat available for recovery at all times.

Recognizing the disparity between the time that this energy is available for recovery and the time when it is needed by the scalder, Georgia Tech engineers suggested that a storage component be designed and installed as part of the desuperheater system. Through funding provided by the Georgia Department of Agriculture at the request of the Georgia Poultry Federation, Tech engineers were able to provide

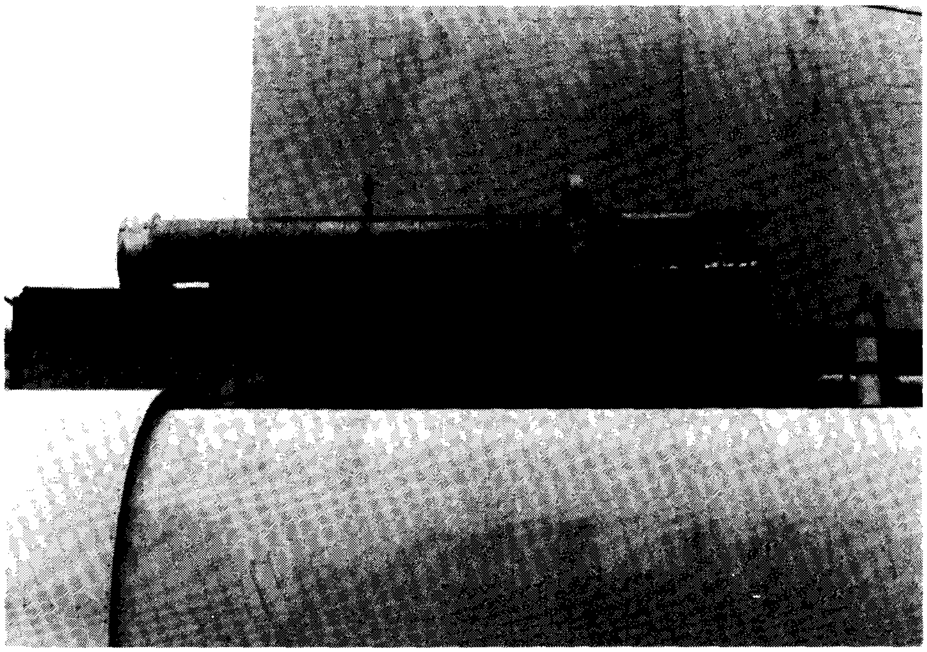


FIGURE VI-1 DESUPERHEATER
- side view -

FIGURE VI-2 DESUPERHEATER
- end view -

technical assistance to Gold Kist personnel in specifying a hot water storage tank during the 1981 fiscal year.

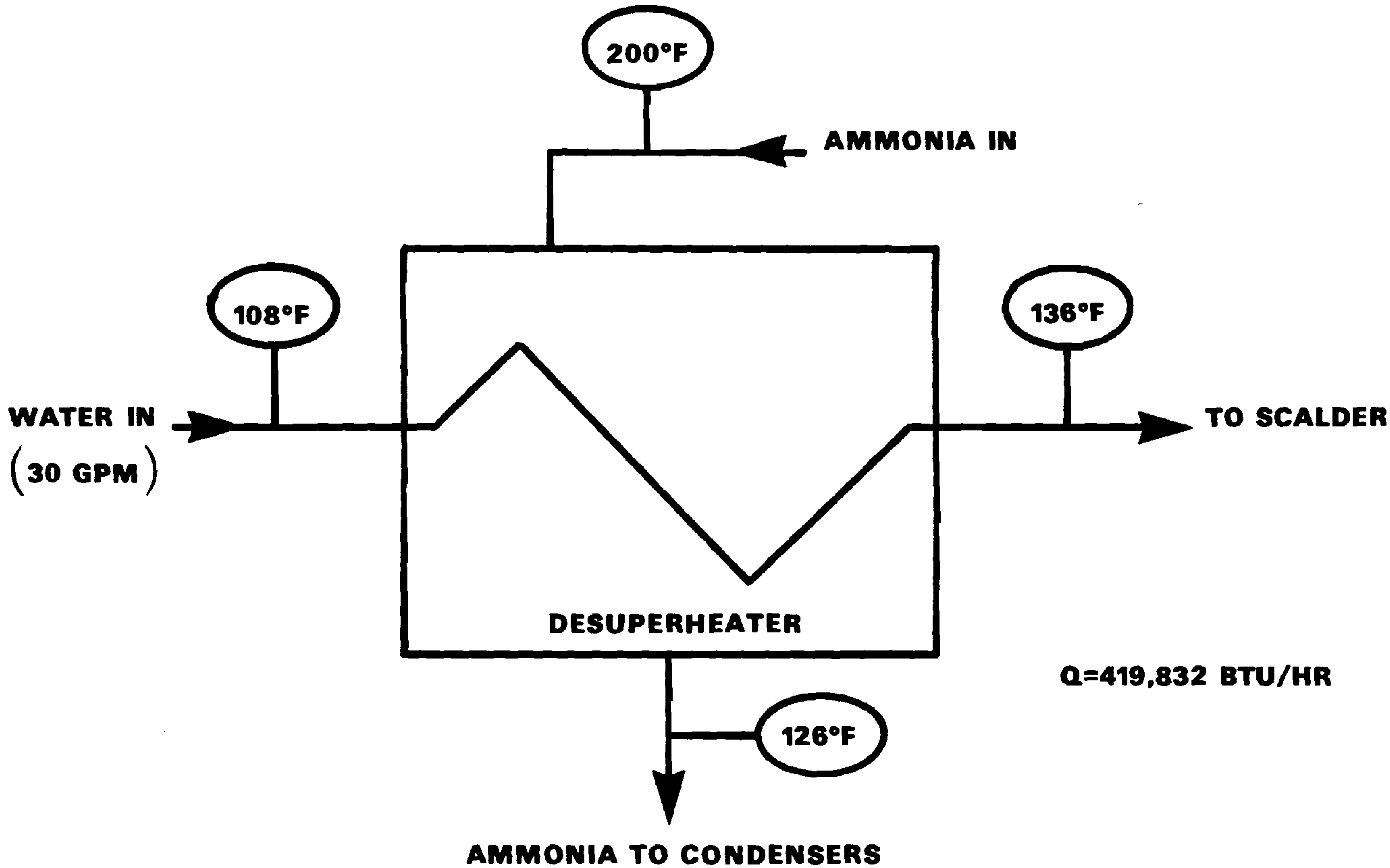
Desuperheater System Capabilities

Installed in June 1979, the shell and tube ammonia desuperheater was sized to recover 567,720 BTU per hour from the hot refrigerant. Actual data taken indicated the average heat recovery rate to be 419,832 BTU per hour due to the flow rates on both the shell and tube sides of the unit being less than anticipated. A summary of the unit's performance is given in Figure VI-3. These figures indicated that the potential existed to recover 10 million BTU of superheat per day.

Storage Potential

Since processing only occurs during 16 hours of the day at the Ellijay plant, over 3 million BTU of recoverable heat is unusable. Combining this with the 20 million BTU available over the weekend, a discrepancy of 23 million BTU of recoverable but unuseable heat results. In order to take advantage of the full potential of the ammonia desuperheater system, a component to store the recovered heat until it is needed at the scalder should be added to the system.

Funds to purchase and erect the storage component were provided by Gold Kist. Engineers of the Engineering Experiment Station's Technology Applications Laboratory were asked to design the storage facility for the plant.



DESUPERHEATER SYSTEM PERFORMANCE

FIGURE VI-3

Because the USDA requires 0.25 gallons of scalder water overflow for each bird through the scalder, large amounts of water are demanded by the unit during processing. By storing the recovered heat in a tank of water, both the temperature and makeup water requirements of the scalder could be satisfied at a later time.

A material balance was performed on the storage component of the system and a 15,000 gallon tank was found to provide sufficient capacity for the Ellijay desuperheater system.

Tank Specifications and Purchase

Georgia Tech contacted three possible suppliers of an insulated 15,000 gallon fiber reinforced polyester tank and Gold Kist contacted a fourth. All four vendors submitted preliminary bids and from the information they provided final specifications were developed and an engineering drawing made (See Appendix B).

The final specifications called for a 15,000 gallon FRP hot water storage tank capable of storing potable water at atmospheric pressures and at temperatures up to 190°F. The tank was to be insulated to an R value of R-9 to minimize heat loss from the tank surface. The specifications also requested that the vendor submit for approval a detailed engineering drawing of his tank prior to construction. At this time, last minute additions or deletions could be made without wasting manufacturing time or money.

After completing the design, Tech engineers turned the final specifications over to Gold Kist so they could submit a request for final bids. Gold Kist decided to ask for a final bid from only one vendor; the Southern Pump & Tank Company (SPATCO) of Winston Salem, North Carolina. SPATCO has provided many storage tanks to Gold Kist in the past so a firm business relationship has already been established between the two firms. SPATCO also submitted the lowest preliminary bid.

Replying to the request with a quotation of $12,533, SPATCO has been awarded the contract for the manufacture of the storage tank. Delivery is anticipated at the end of summer 1981.

Energy Savings Due to Storage Capability

The extra heat than can now be recovered and utilized will translate into savings in energy costs. The Ellijay plant currently produces steam to heat its cleanup and scalder makeup water by burning No. 5 fuel oil.

Based on monitored run time of the ammonia refrigeration system, it is estimated that the system operates at full load 75% of the time. Assuming an overall boiler and steam distribution efficiency of 60%, the annual savings, in gallons of No. 5 fuel oil, S, is developed as follows:

$$S = \frac{419{,}832\ \text{BTU/hr}(88\ \text{hr/wk})(52\ \text{wks/yr})(0.75)}{(149{,}400\ \text{Btu/gal})(0.60)}$$

S = 16,074 gallons of No. 5 fuel oil saved per year.

The yearly dollar savings can be found by multiplying S by the current price of No. 5 fuel oil for the Gold Kist plant:

Annual Savings = 16,074 gallons/year ($0.70 per gallon)

Annual Savings = $11,252 per year saved

If the capital invested in the purchasing and erecting of the storage tank totals $20,000, then a simple payback on investment of 1.78 years results.

Future Work

During the coming fiscal year Tech engineers will develop a computer optimization procedure for designing heat recovery systems. This optimization scheme will feature a thermal storage option. Once completed, the program could be used by members of Georgia's poultry industry in determining the best heat recovery system for their particular application.

An intermediate loop heat exchanger will be designed and installed at the Gold Kist Ellijay plant as part of the ammonia desuperheater system. Propylene glycol will be circulated through the tubes of the desuperheater to capture the heat released by the hot ammonia vapor. The heated glycol solution will then enter a plate and frame heat exchanger similar to those employed in poultry processing plants for recovering waste heat from scalder overflow water where it will give up its heat to a potable water stream being recirculated through the storage tank. Although some efficiency may be lost in the heat transfer process due to the intermediate loop, it will help minimize problems of thermal expansion which have caused failure in the tubes of the desuperheater.

Data will be taken on the completed system and its performance analyzed. Once performance levels are determined system data will be utilized in the optimization program discussed above.

Tech engineers hope that the completed heat recovery system at the Ellijay plant will supply almost all of the hot water needs of the scalder and the high pressure plant cleanup system. To economically approach self-sufficiency in these systems would represent a tremendous energy savings in the poultry processing industry.

REFERENCES

1. Boykin, W.B., Combes, R.S., Energy Conservation in the Poultry Processing Industry, Final Report on Department of Energy Contract DE-AS05-77CS40094, Georgia Institute of Technology, Engineering Experiment Station, Technology Applications Laboratory, Atlanta, Georgia, March 1980, 147 pgs.

SECTION VII

SOLAR ENERGY APPLICATIONS

by W. D. Holcombe and S. D. Robertson

Introduction

The Georgia Institute of Technology Engineering Experiment Station, funded by the Georgia Department of Agriculture has been investigating the potential for alternative energy use on poultry farms since 1974. In 1975, studies were begun to determine the feasibility of directly utilizing solar thermal energy on a broiler farm. Since then, two low cost solar air heating systems have been built and operated. Work is continuing at these demonstration sites.

A number of problems have been identified at the two demonstration sites. Much of the effort during the last two years has been directed at solving these various material and design problems. In addition, the data acquisition capability has been improved. Most recently, data reduction capabilities have been greatly improved. These topics are discussed in detail in the following section.

Passive Solar Heating System

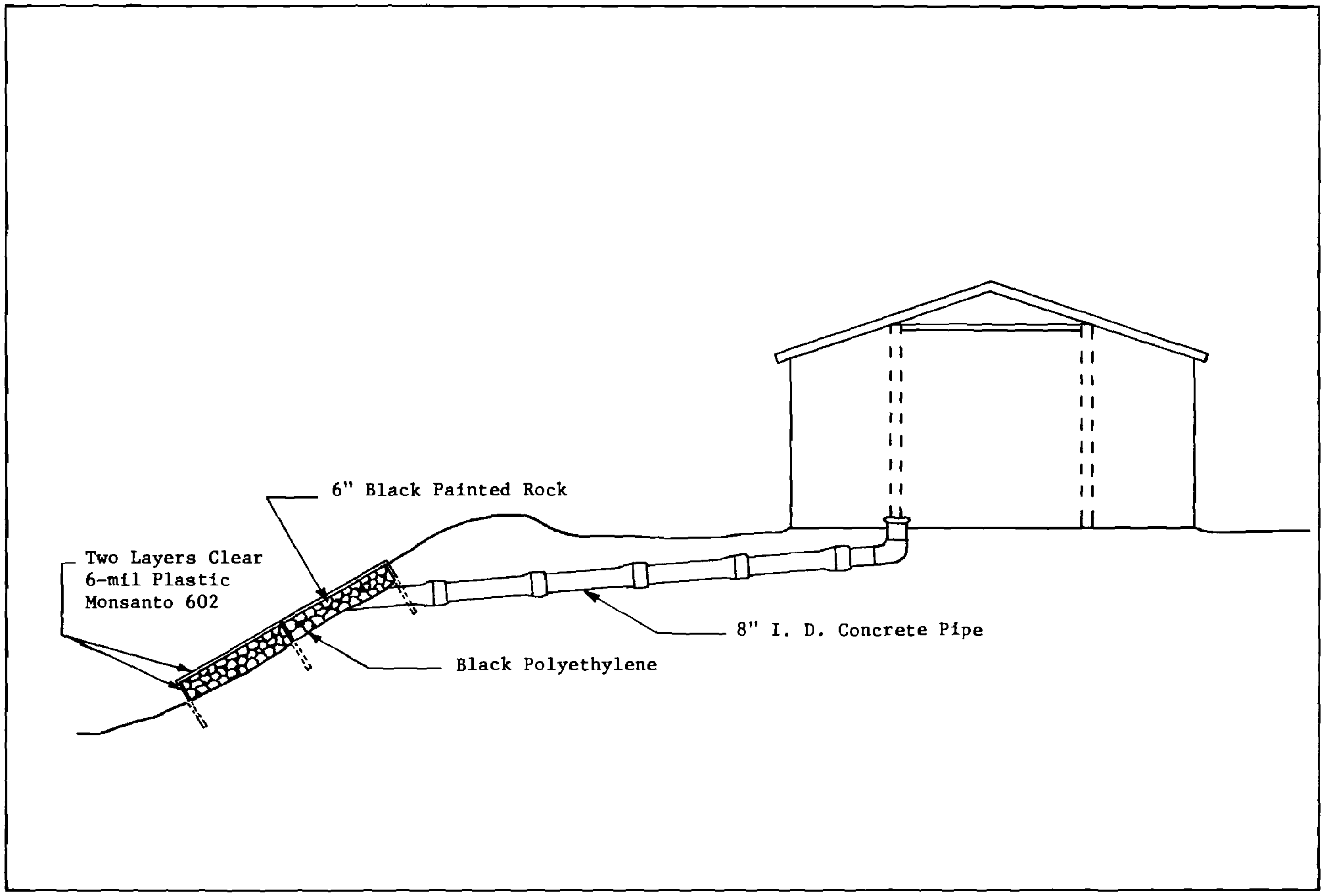
Description and Background

In May, 1976, a passive solar heating system was built on Lamar Hick's poultry farm near Cumming, Georgia. The system was designed to provide part of the heat needed in one of his three broiler growout houses. Conventional natural-gas-fired brooders were used to heat these houses. Since that time, some performance monitoring has been conducted and various system changes and improvements have been made.

Two important criteria for this system design were that it be low cost and easily built on site by a farmer. A remote, passive solar air heater was chosen for this design. This design selection was made possible because of the nature of the building site. The ground was used for the collector structure; no pumps, fans, or electric controls were used; and simple manual controls were provided.

Low cost materials were used in the original construction of the passive solar air heater. A six-inch-deep, granite rockbed was used as the absorber surface. The average diameter of the granite rocks was four inches and about eighty tons of granite rock were used. To increase the absorbitivity of the rockbed, it was sprayed with black paint. The glazing for the collector was composed of two layers of six-mil thick, clear polyethylene film, treated to prevent ultraviolet degradation. Thirteen outlet ducts, made of eight inch diameter concrete pipes, connected the collector to the growout house. The collector was built on a 30° hillside behind the broiler growout house and faces 30° east of south. A schematic of the original system is shown in Figure VII-1.

Radiation from the sun heats the rockbed thus raising its temperature. Air in the collector is then heated by the rockbed. As the air is heated, it rises naturally through the collector and into the broiler growout house. The total cost to build this 3328 square foot collector was approximately $6600 in 1976.



Solar Heated Broiler Growout House

FIGURE VII-1

Evaluation of performance data over the past winters showed the collector was not operating as effectively as expected. The major causes of the low efficiency were:

1) no insulation on the outlet ducts,
2) no plenum to direct the heated air from the collector to the outlet duct,
3) improper ratio of collector area to outlet duct area, and
4) material degradation.

These problems are detailed in References 1 and 2.

Experimental Modification

Because of these problems, an experimental program was undertaken during August, 1979, to determine the effect of various design changes on collector performance. In this program, a 16' x 16' section of the collector was sealed off from the rest of the collector. This section was modified by:

1) increasing both the inlet area and outlet area to four square feet,
2) adding an above ground outlet duct,
3) adding a plenum to direct the airflow from the collector to the outlet duct, and
4) installing new polyethylene glazing.

The results of this test program showed that these changes increased the efficiency of the collector. Therefore, a plan was proposed to divide the entire collector into ten individual test sections. In this way, the effect of various design parameters on the collector's performance could be determined. The approach was to change a specified design parameter on each section thereby making it different from the other sections. Each section was then to be monitored to determine the amount of useful heat energy it added to the growout house. The performance results for each section were to be compared to determine which design parameters significantly affected the collector efficiency. Also, this testing would show how the collector efficiency changes with respect to each design parameter.

The design changes to be made to the collector included:

- above ground outlet ducts for all sections
- different ratios of collector area to outlet area
- different air gap heights, which is the distance between the rockbed absorber surface and the lower glazing, and
- different glazing materials which have a longer expected life than polyethylene.

The detailed modification was detailed in Reference 2.

A list of deliverables and drawings detailing the modifications to be made to the collector was prepared and sent to two contractors for bid in Fall, 1979. Both contractors responded with considerably different estimates. One estimate was for about $19,000 and the other was for about $10,000. Since both of these estimates were greater than the amount budgeted for the Cumming demonstration project, the proposed collector modifications were postponed until the start of FY '81.

Collector Modifications

During the summer of 1980, the proposed collector modifications were reviewed. A decision was made to reduce the extent of the collector modification from the entire collector to five sections. These five sections would allow a comparison of two glazing heights and two collector area to outlet area ratios and allow a comparison of forced and natural flows. Tasks involved in the collector modification included:

- design
- material and component selection
- material and component purchase
- component fabrication
- site preparation
- component installation
- instrumentation installation

Figures VII-2 and VII-3 are drawings of the final collector design. Four 16' x 16' natural flow sections and one 8' x 16' forced flow test section were constructed. Sections A and D had a collector area to outlet area ratio of 60:1. Sections B and C had a collector area to outlet area ratio of 107:1. The glazing height of each section was modifiable.

Material and component selection was based on the selections made for the previous modification design. The original design called for an on-site evaluation of eight different glazing materials. It was

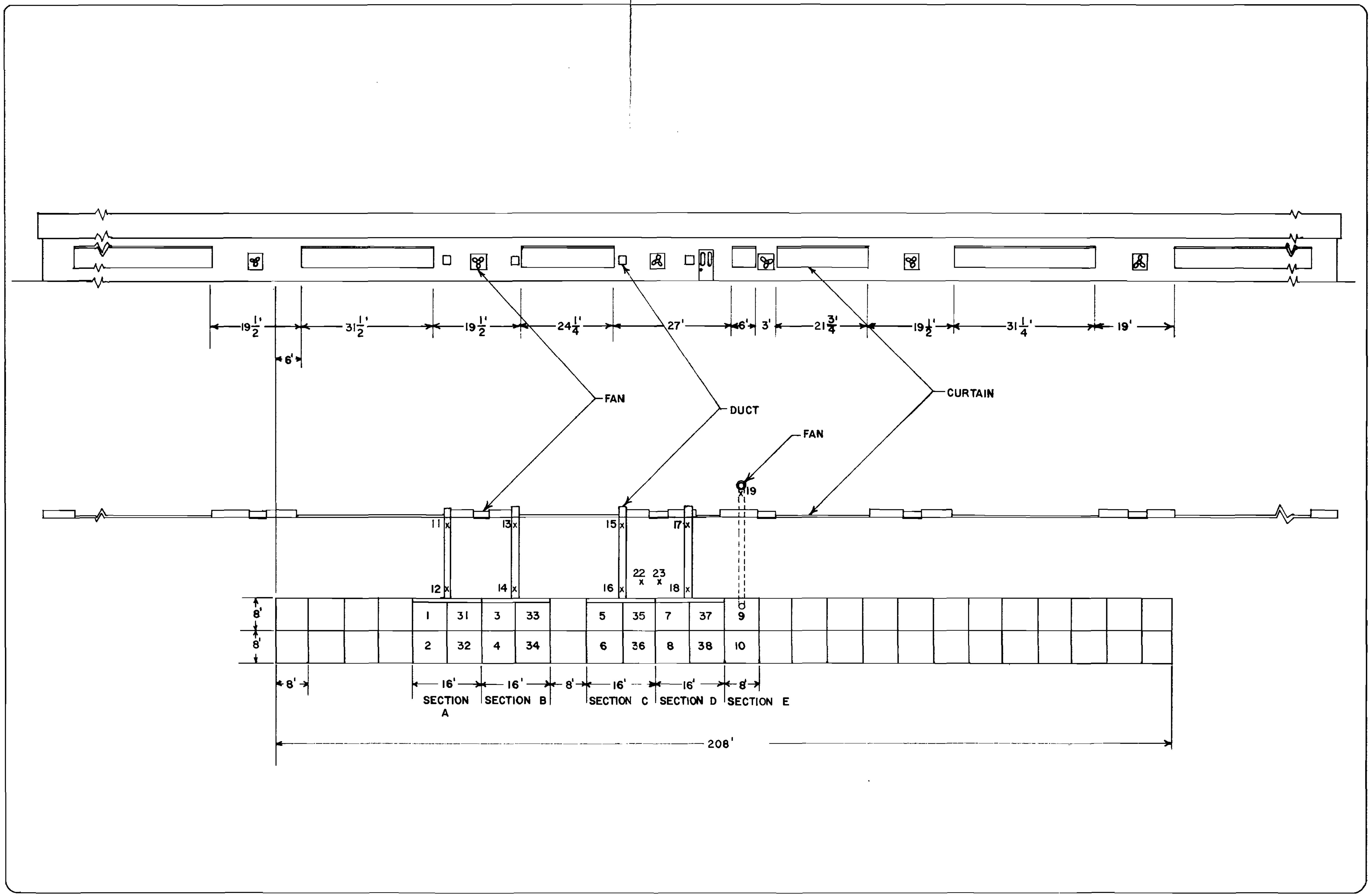


FIGURE VII-2 COMPLETED TEST SECTIONS

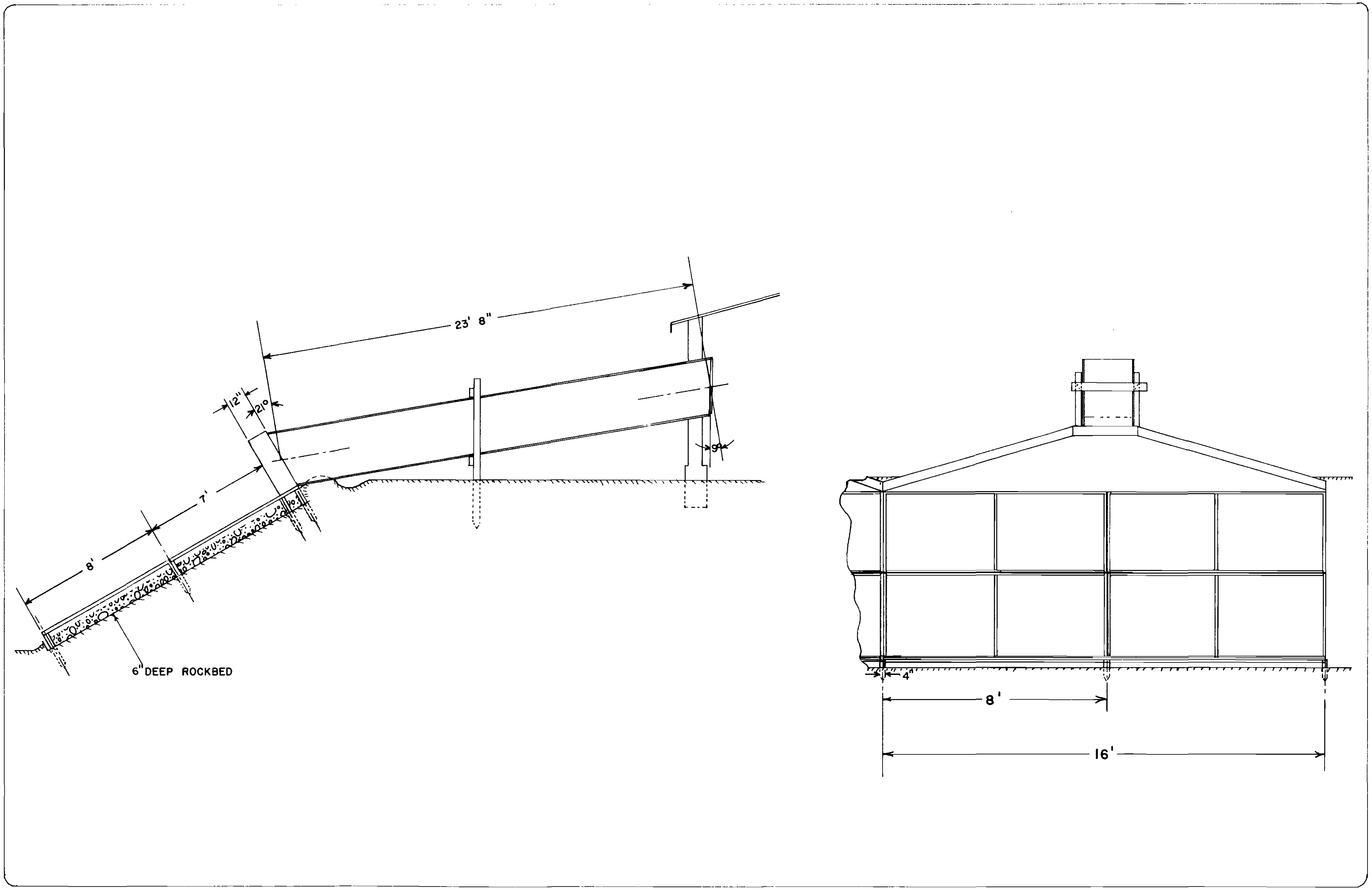


FIGURE VII-3 TEST SECTION ELEVATION

decided that one glazing would be appropriate for this smaller scale experiment. Several glazing materials were considered including polycarbonate double-glazing systems, fiberglass reinforced plastics, and polyester film. These materials are summarized in Table VII-1. Melinex®, a 7-mil, UV-stabalized polyester film, manufactured by ICI Americas, Inc., was selected as the glazing material. The manufacturer was cooperative in supplying the required amount of glazing material at no cost. William Wilhelm of Brookhaven National Laboratory indicated that he had good success with this material for extremely low cost ($1 per square foot) collectors. He recommended two adhesive products for attaching this film to the frames and indicated that the material should be heat shrunk after attachment to obtain a tight fit.[3] Painted 2" x 2" fir was chosen over steel or aluminum glazing frames due to cost and fabrication considerations.

The original modification plan called for a glazed, 2' x 2' frame plenum. This design was replaced with a lightweight plywood 1'x 2' plenum insulated with 3 1/2-inch fiberglass batt. These plenums were more durable and reduced the heat loss at the top of the collector. Square-cross-section, galvanized steel ducts were selected. Standard, 1-inch fiberglass duct insulation was selected with a weatherproof coating for application to the duct exterior. An installed duct and plenum are shown in Figure VII-4.

Material and component purchases were begun in September, 1980. The sheet metal ducts were ordered and lumber was purchased for the glazing frames and plenums. The glazing frames and plenums were

TABLE VII-1
GLAZING MATERIALS

Material	Price ($/ft²)	($/ft² of double glazing)	Availability
Polycarbonates			
o Park Energy Systems	2.30	2.30	4-6 weeks
o Qualex	1.85	1.85	1-4 weeks
o CY/RO			
o Tuffak-Twinwal			
Fiberglass Reinforced Plastic			
o Filon	.56	1.12	--
o Glasteel		.50	1.00 Immediate
Polyester film			
o ICI		.24	.48 Developmental

Note: Prices as of Fall, 1980

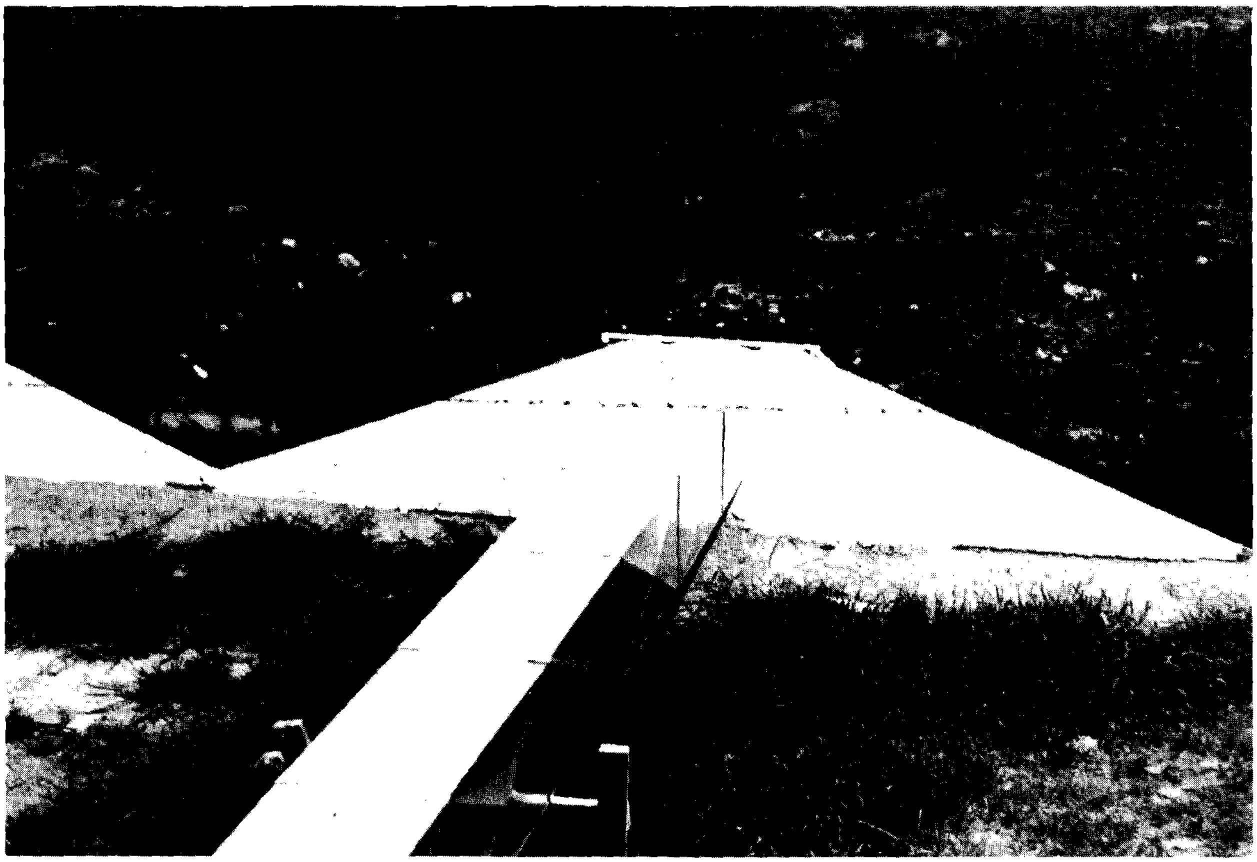


FIGURE VII-4 INSTALLED DUCT AND PLENUM

assembled at Georgia Tech by cooperative program students and a graduate research assistant. Arrangements were made to obtain a 60-inch roll of Melinex®. Densil 2078, 2-mil, pressure-sensitive adhesive was ordered for attaching the glazing to the frames.

After assembly, the plenums were insulated with 3-1/2-inch fiberglass batt. Then, the wooden plenums and glazing frames were primed and painted. Glazing installation was then begun. The glazing frames were wrapped with glazing similar to wrapping a package. Adhesive was used between the glazing and the wooden frame to ease the installation. Most of the adhesive was used to attach glazing to glazing. It was necessary to use two pieces of glazing per frame since the glazing was only 60-inches wide while the frames were 8 feet wide. This procedure took approximately one week for a two-person crew.

Charles Allen of ICI[4] and William Wilhelm of Brookhaven National Laboratory[5] both recommended heat shrinking the glazing onto the frames. Mr. Allen recommended 250°F for 15 minutes. Attempts were made to heat shrink the glazing in a site built oven using a kerosene fired heater. The necessary temperatures were not achievable in this oven. Arrangements were made to use an oven at a local skylight and plastic specialties manufacturing facility. A crew of three was able to heat shrink the glazing on twenty frames in about three hours. The result was a good tight fit over the glazing frames. Installed glazing frames are shown in Figure VII-5. The heat shrinking process appears important. It is unlikely, however, that it can be performed on site at a poultry farm.

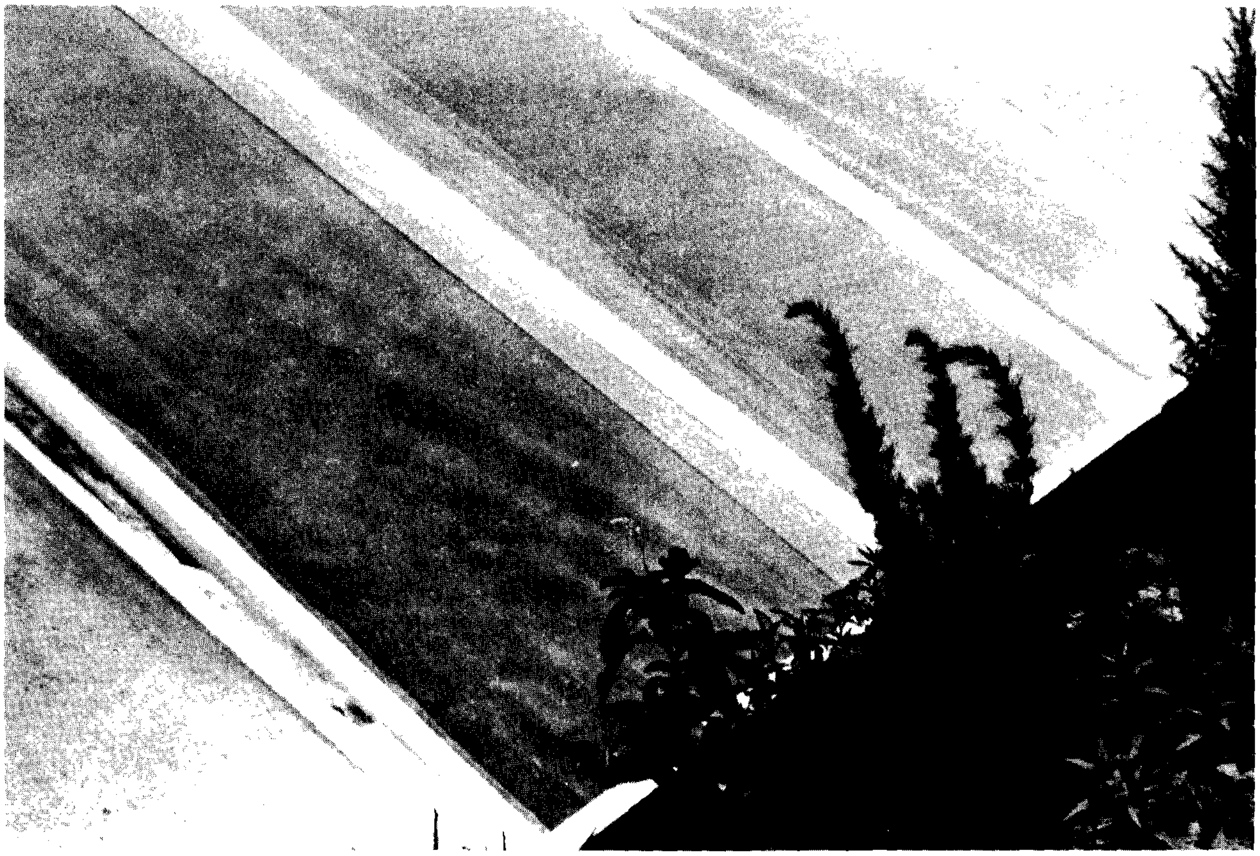


FIGURE VII-5 INSTALLED GLAZING FRAMES

A considerable amount of site work was required before the new collector components could be installed. The old glazing frames were removed. Eleven new pressure treated 4" x 4" posts were installed near the top of the rockbed to support the new, shorter, top glazing frames and plenums. Plywood strips were installed to separate the individual test sections from each other. New thermocouples were installed in the rockbed. The rockbed was then repainted with Rust-O-Leum 412, flat black paint.

After completion of the site preparation, component installation was begun. Two carpenters were hired to aid Georgia Tech researchers, with the installation. The plenums and ducts were installed, the ducts were cut in through the side of the chicken house and framed in, and doors were installed on the duct outlet. A collector outlet is shown in Figure VII-6. This effort took approximately 128 manhours. Glazing frames were the last item installed at the site. Finally, new thermocouples were placed in the ducts. The completed modification is shown in Figure VII-7.

Instrumentation

The instrumentation at the demonstration site consisted of thermocouples, a Li-Cor LI200S pyranometer and integrator, and gas meters. An Esterline-Angus chart recorder was used to record temperatures and solar insolation.

Preliminary Evaluation

Winter performance data is unavailable because of the late completion of the collector modifications. Measurements were made on

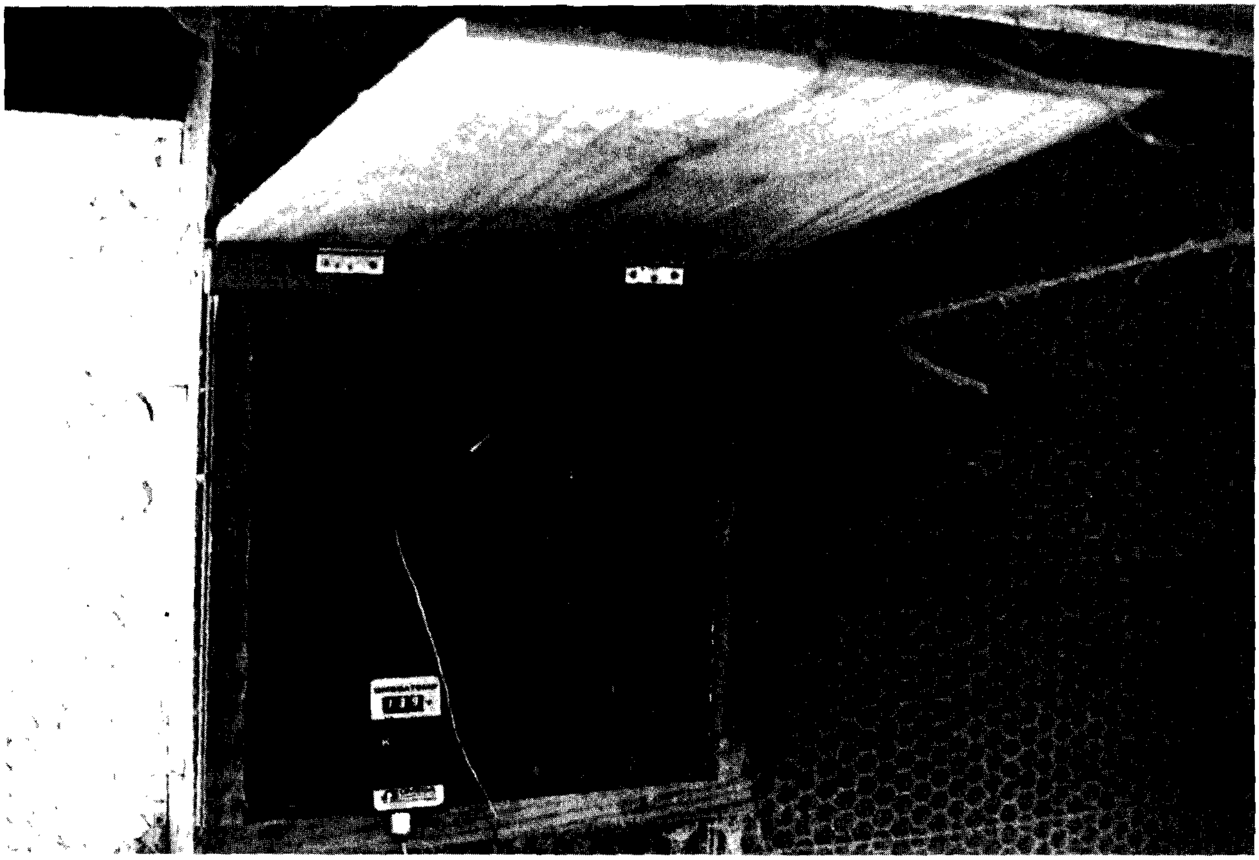


FIGURE VII-6 COLLECTOR OUTLET

FIGURE VII-7 COMPLETED COLLECTOR MODIFICATION two occasions in late spring. For example, with a mid-afternoon ambient temperature of 95°F, the temperature at the outlet of the ducts was 140°F. The natural correction flowrate for one 18" x 18" duct was approximately 170 cfm. The glazing was not sagging and seemed to be holding up well after over two months in the field. Weeds were, however, blocking much of the collector air inlet.

This preliminary information is encouraging, indicating that significant performance improvements may have been gained due to the collector modifications. Heating season data must be collected to confirm this and evaluate quantitatively the benefits of the system. It appears that special attention must be given to the maintenance of the system.

Conclusions

The initial system design had a number of deficiencies including:

- o no insulation on outlet ducts,
- o no plenum to direct the heated air from the collector to the outlet duct,
- o improper ratio of collector to outlet duct area, and
- o material degradation.

Problems such as these should be avoided in future system designs. Also, the disadvantages inherent to remote rockbed collectors must be considered when comparing them to alternative collector designs. These disadvantages include:

- o additional labor and materials for ducts connecting the collector to the building,

- o energy and pressure losses in the ducts, and
- o high maintenance.

The newly implemented system changes seem to have improved the system performance. System monitoring during the coming heating season will be required to assess the actual impact of the changes as well as the life of the newly installed materials.

Future Work

Data will be taken at the Cumming site during the 1981-1982 heating season to determine what performance improvements, if any, have been gained by the modifications. The test sections will be compared to learn the importance of the collector area to outlet area ratio and of the glazing height. A comparison will be made between the natural convection sections and the forced convection section. Observations will be made on the durability of the collector components and materials.

Active Solar Heating System

Description and Background

A low cost, active solar heating system was built on Mr. William Waddell's farm near Villa Rica, Georgia in April, 1978, to augment the propane fired brooders in one of his growout houses. Figure VII-8 is a photograph of the solar collector on the roof of the growout house. Figure VII-9 shows the distribution ducts inside the house. Figure VII-10 is a cutaway view of the system. Outside air is pulled from

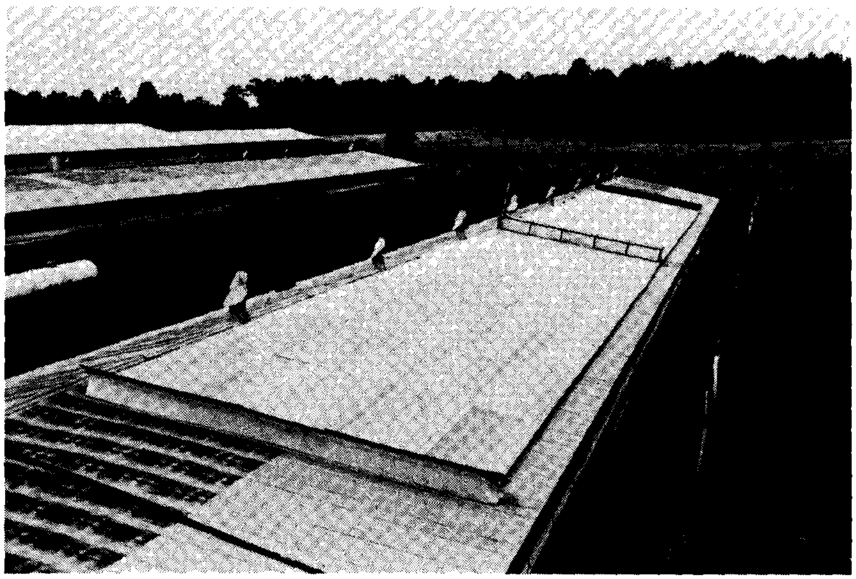


FIGURE VII-8 ACTIVE SOLAR COLLECTOR

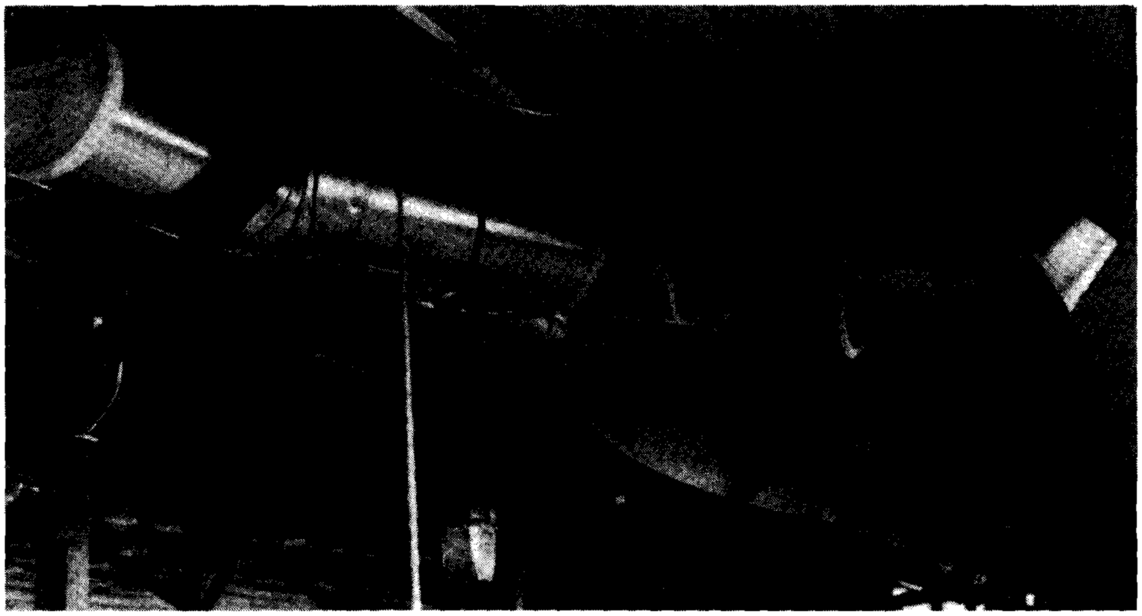
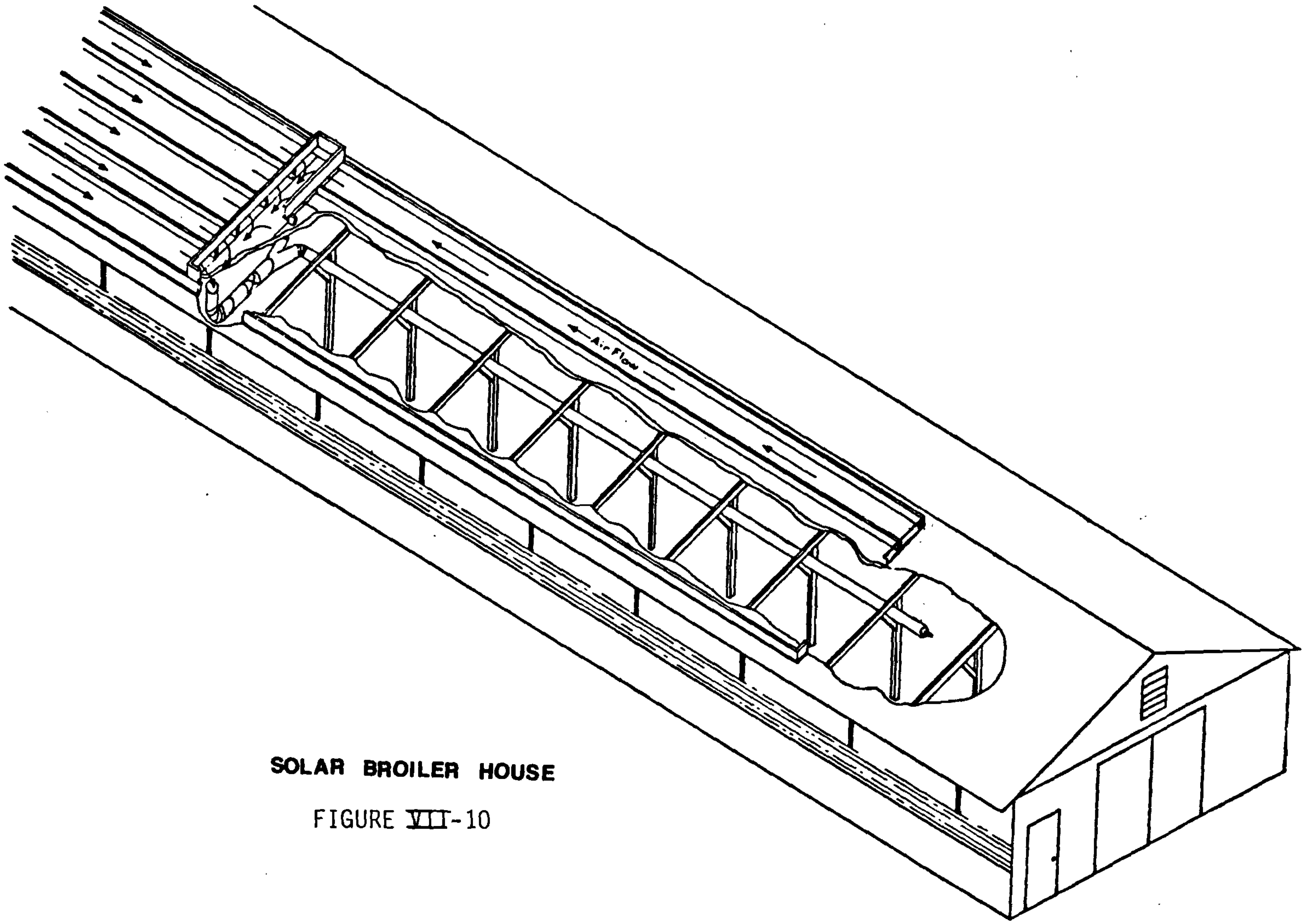


FIGURE VII-9 FAN AND DISTRIBUTION DUCTS



SOLAR BROILER HOUSE

FIGURE VII-10

each end of the collector through five parallel channels between the collector glazing and absorber surface to a central plenum. A duct fan pulls air from this plenum and distributes it to the house through polyethylene ducts which run the length of the house. The system was operated and monitored during the 1978-1979 heating season.

Cost was a major consideration in the original design and material selection process. The 2950 square foot collector was built on site using Kalwall fiberglass sheet for the glazing and a black, foil-faced insulation board to absorb the solar energy and reduce heat loss from the collector. The system was built for about $2.45 per square foot of collector in 1978.

A number of things were learned in operating the system. The forced air system was designed to pull make-up air either from the house or from the outside. It was apparent soon after start-up that the house air was too dirty to be pulled directly through the collector. The system was operated using ambient air as make-up. The volume flow of air was small enough to be below the minimum ventilation requirement during most operating periods. It is possible that the house air could be filtered and recirculated, as evidenced by the installation of a filter at the Georgia Tech wood heated growout site.

A number of problems have arisen which serve to reduce the efficiency of the solar air heater. They include dust buildup on the collector surfaces, material degradation, design problems, and improper system control. These problems have been detailed in

References 1 and 2. The solar collector was rebuilt during the winter and spring of 1980 in an attempt to correct some of these problems. During the collector rebuilding, a new absorber surface was installed, the glazing was cleaned and reinstalled, and the control system was replaced. Also, filters were installed on the air inlets to reduce the amount of dust being pulled into the collector. At the same time, a new data acquisition system was installed. The collector rebuild and the data acquisition system are described in Reference 2.

Instrumentation

The instrumentation and data collection system at the Villa Rica site has been improved. A Datel cassette digital data recorder along with a data reader was obtained in July of 1979. The digital data recorder was interfaced with the existing Esterline Angus 24-channel chart recorder in Spring, 1980. This interface involved modifications to the Esterline Angus chart recorder and design and construction of sample/hold circuits. These sample/hold circuits store the analog measurements taken by the Esterline Angus recorder. The digital data recorder then reads this information stored by the sample/hold circuits. This permits use of the thermocouple reference circuitry of the Esterline Angus recorder and allows the digital data recorder and the chart recorder to cycle at different cycle rates. The Esterline Angus chart recorder, the digital data recorder, and the solar radiation integrater have been mounted in a nineteen-inch electronics cabinet which has been sealed to protect the equipment from the dusty environment of the growout house. A manual was written to document the sample/hold circuits and their interface to the chart recorder and digital data recorder. New thermocouples, installed as the collector was rebuilt, provide temperature profiles along the top flow channels and measure the exit temperature for each of the ten collector channels. Other thermocouples measure ambient, house, and collector outlet temperatures. A Li-Cor LI200S pyranometer is used to measure total solar insolation on the plane of the collector. In addition, gas meters were used to measure the propane consumption of the infrared brooders. The instrumentation was used to monitor the solar air heating system during the 1980-1981 heating season.

Monitoring Program

The solar heating system was put into operation on November 10, 1980. Data was collected from November 10, 1980 until March 8, 1981 when the system was shut down for the summer. Visits were made to the site to change the paper chart and data cassette tape as needed. The paper charts lasted approximately 4 weeks, the cassette tapes lasted approximately 4 weeks. Site visit reports were filled out each time. A sample site visit report is included in Appendix C. The farmer was contacted periodically to learn of any system operating problems.

Problems

Certain problems continue to be evident at the Villa Rica site. Shortly after startup, the system had to be shut down because of a fan failure. This fan has given repeated problems, possibly because of the high temperature application. The fan shaft and bearings were replaced. A keyway was cut in the new shaft and a cast iron pulley was installed in place of the original aluminum pulley. The fan operated the remainder of the season without incident.

Dust is a continuing problem. It is building up in the collector and leaking into the sealed instrumentation cabinet. Sealing of the site built collector itself is also still a problem.

Data Analysis Equipment

A Datel data cassette recorder was purchased along with the data cassette reader in July of 1979. In July of 1980, the selection process was begun for a mini-computer to use for the data reduction. There were a number of requirements for this piece of equipment. They included a 16-bit, parallel interface for use with the Datel tape reader; an IEEE-488 interface for use with an existing four color plotter; sufficient internal storage for data arrays; and permanent tape or disk storage for software and reduced data. Other considerations included ease of programming, printing capability, display type, and software available for purchase. Several mini-computers were considered including the Hewlett-Packard HP-85, Apple II, Commadore-Pet, and Cromemco CS-2.

The HP-85 was chosen for a number of reasons. The HP-85 has the keyboard, CRT, printer, and tape drive packaged in one unit. The required interfaces were available. Additional software and special ROM's were available from Hewlett-Packard. The entire package could be purchased from one manufacturer, there would be no compatibility problems arising from the use of equipment from two or more suppliers. The cost was competitive with the next best alternative.

The EDP Request was filed in August, 1980. Approval was finally granted on November 3, 1980 and the Purchase Order was placed on November 6, 1980. The equipment was received in mid-December 1980. The purchase included the HP-85, an HP-IB (IEEE-488) interface, a 16-bit parallel interface, a Plotter/Printer Rom, and a Matrix Rom.

Computer/Tape Reader Interface

The purpose of the computer/tape reader interface is to transfer digital information from the tape reader to the computer in an orderly manner. Because the tape reader and the computer were made by different manufacturers this was not a simple "plug-in" operation. Instead, it required that wires from the computer used for data transfer and timing control be soldered to the tape reader.

The basic operation of the interface is described below. The first step is to start the tape drive motor which moves the tape off the leader tape and onto the oxide. Pulsing the INIT (initialize) line by using the instruction CLEAR 409 does this.

Once on the oxide the data transfer cycle begins. The first step is to start the tape drive motor. Pulsing the STRT (start) line by using the instruction CLEAR 408 performs this function. With the tape moving, the tape reader reads the first 16 bit word that it encounters. The tape reader signals that a word has been read and is ready for transfer by setting its WORD RDY (word ready) line to the

True state. The WRD RDY line controls the state of the FLGA (Part A Flag) line on the HP-85. Thus, when the WRD RDY changes from False to True, it simultaneously changes FLGA from the Busy state to the Ready state. Meanwhile, the computer has been checking for a Ready indication on the FLGA line. Once it sees that the FLGA line is Ready, the interface requests data by setting the CTL (control) line in the True state. The CTL line controls the state of the WDT I (Word Taken Input) line on the tape reader. When the CTL line changes state from False to True the WDT I line simultaneously changes State from False to True.

The change of stăte from False to True on the WDT I resets the WORD RDY line from True to False. Since the WORD RDY line controls the FLGA line, it also changes state from Ready to Busy. When the interface sees that the FLGA line is in the Busy state it inputs the data to the computer. The digital data is input through 16 parallel data lines. Each line transfers one bit of information. The interface then signals that it has received the data by returning the CTL line to the False state.

At this point the first 16-bit word has been transferred and the computer is ready to start again. Meanwhile, the tape is still moving forward and the tape reader reads the next 16-bit word. This word is transferred to the computer in the same manner. This process is continued until all the 16-bit channel words and one 48-bit clock word in a file have been read and transferred to the computer. When one file is read the tape stops. This marks the end of one data transfer cycle. At this point, the data transfer cycle is started again by activating the tape drive motor, transferring another file and then stopping the tape drive motor at the end of the file. One file contains one 16-bit word corresponding to each channel recorded by the datalogger. Also at the end of the file is a 48-bit clock word which corresponds to the time the file was recorded onto the tape by the datalogger. As an example, if the datalogger were set to record 24 channels, as was done in Villa Rica, then each file would have 24, 16-bit words and one 48 bit clock word. The specifications of the interface between the HP-85 and the data tape reader are given in Appendix D.

Once the computer receives the data from the tape reader, the data analysis can begin.

Data Analysis

Energy Savings

For the period October 31, 1980 to March 8, 1981 the solar heating system reduced the energy consumption of the growout house by about 13.5%. This is an actual gas savings of about 9900 ft^3 or 269 gallons of propane. Assuming an average propane price of 69¢/gal over the winter heating season, the resulting savings was $185.

The energy savings is calculated by comparing the energy used in the solar house with the energy used in an identical size house having conventional brooder heat only. These houses are located next to one another and are oriented in the same manner. Therefore, they should experience roughly the same environmental conditions. Also, both houses contained the same number of flocks during this period. Consequently, the energy usage patterns for both houses should be very similar. Although the comparison method may have some inaccuracies, in this case it appears to be reasonable.

Collector Performance

The daily collector efficiency ranged between 18% and 20% for typical sunny days. By definition, collector efficiency is the ratio of useful heat input into the house to the amount of heat available from the sun. For this collector, the instantaneous efficiency and daily efficiency are about the same.

The collector efficiency is computed from the incident solar radiation, the collector inlet temperature (ambient temperature), and the collector outlet temperature and flowrate. The solar insolation, collector outlet temperature, and ambient temperature are plotted versus time of day for two days in January in Figures VII-11 and VII-12. This is representative of data used to compute instantaneous and daily collector efficiences.

A collector efficiency of 20% is normal for solar air heaters. Solar air heaters usually have lower efficiencies than do solar water heaters which have daily collector efficiencies of 30%. This points to the fact that water is a better heat transfer medium than air.

An important concern in building solar air collectors is how air tight it can be made. Air leaks hurt performance by allowing heated

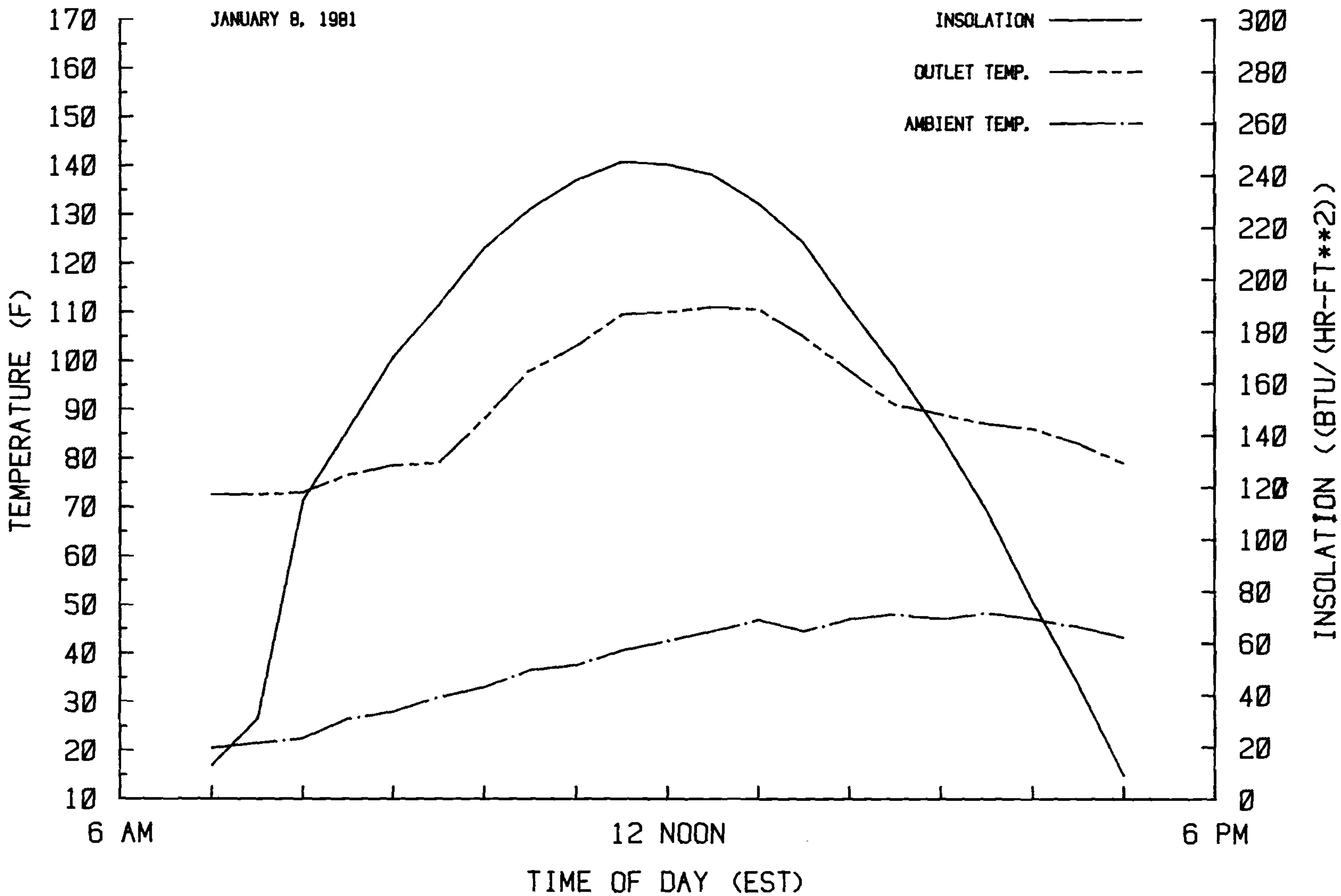


FIGURE VII-11. Collector Performance for January 8, 1981

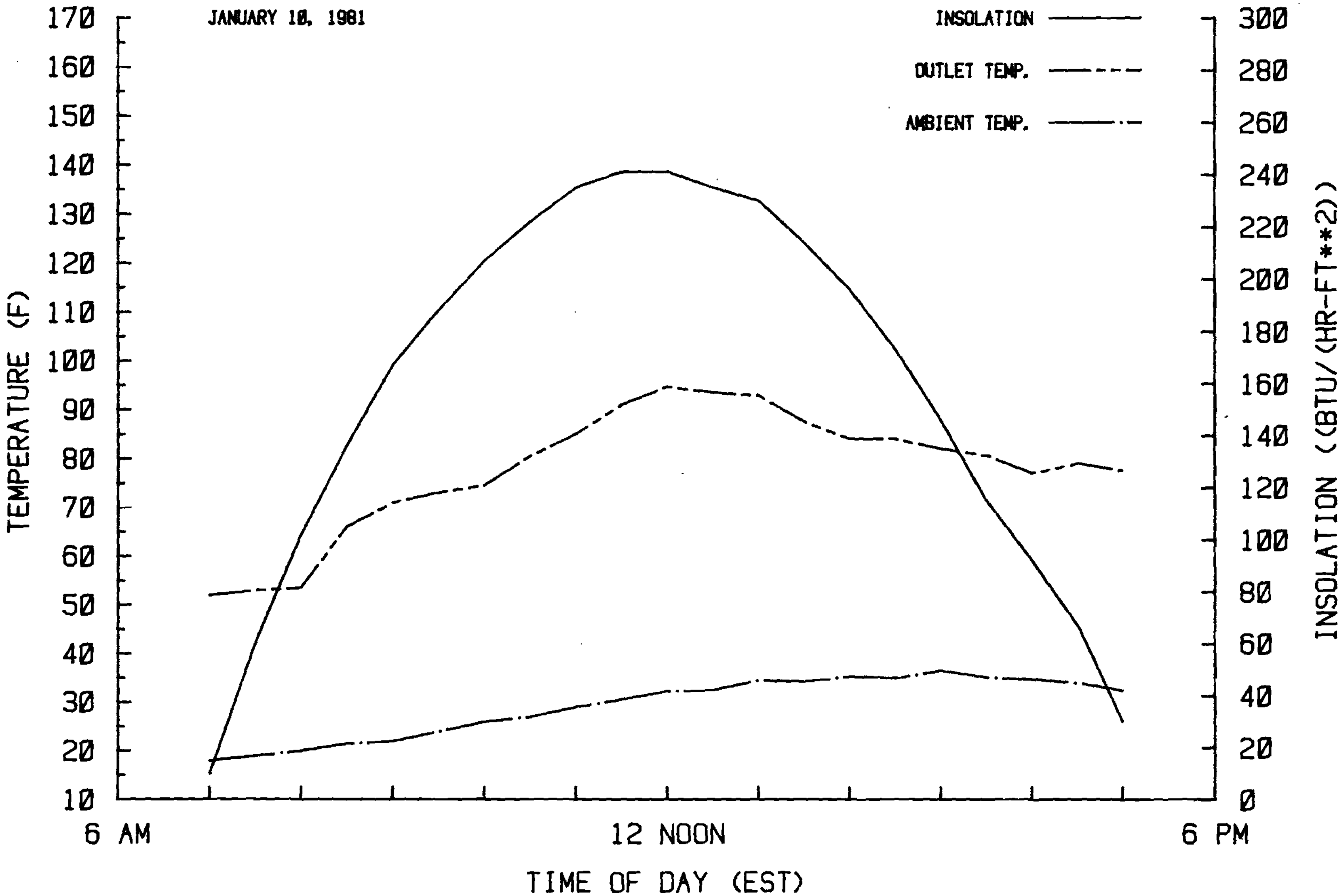
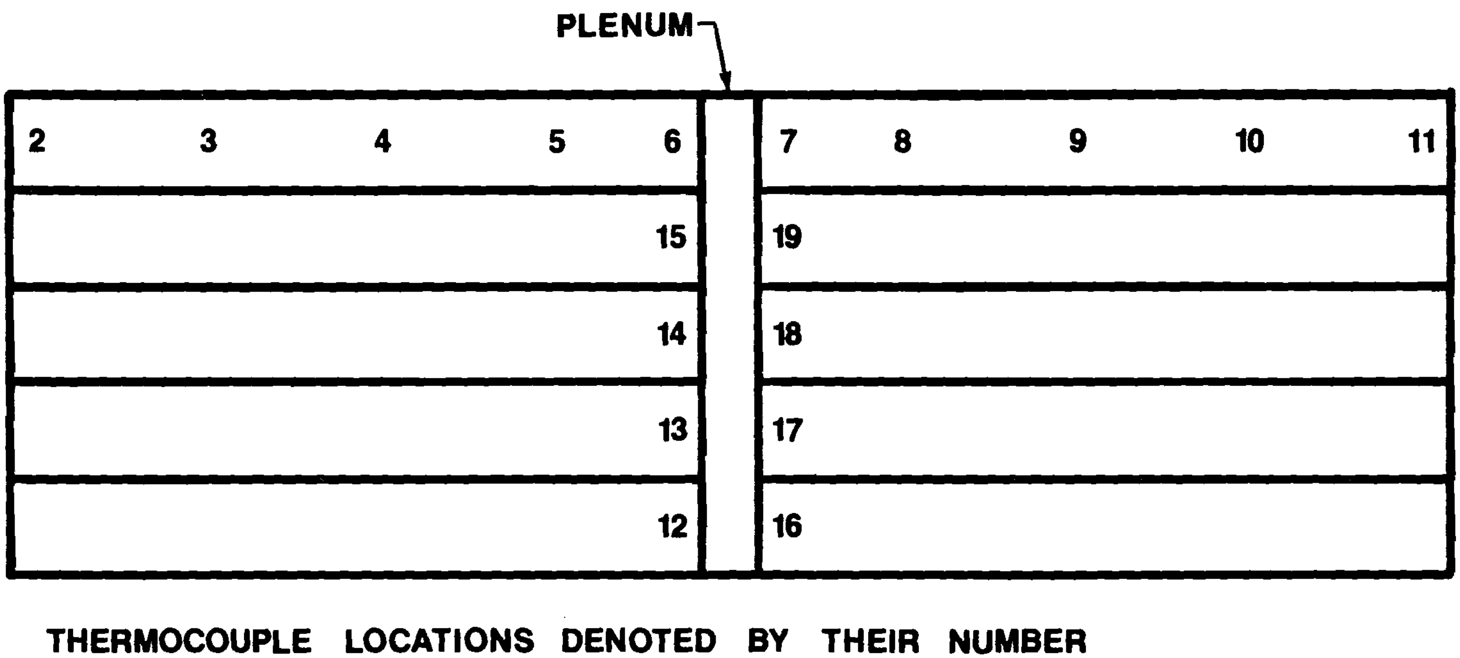


FIGURE VIII-12. Collector Performance for January 10, 1981 air to escape or cold outside air to enter. Since this collector has the fan downstream, it is more prone to cold outside air leaking into the air channels. The cold air mixing with the solar heated air results in a drop in the collector air temperature.

To determine how severe this problem was, 10 thermocouples were installed in the top air channels. The thermocouples, numbers 2 thru 11, provide a temperature profile through the channels. A thermocouple map is shown in Figure VII-13. Figure VII-14 shows a temperature profile through the top channel. (Note: Air enters the collector at both ends where thermocouples 2 and 11 are located and flows to the plenum where thermocouples 5 and 6 are located.) This figure shows the air entering the collector at about 75°F. This is higher than ambient due to some preheating of the air by the tin roof. The air temperature increases as it flows down the channel towards the plenum. This is shown in the left channel by thermocouples 3, 4, and 5 and in the right channel by thermocouples 10, 9, and 8. However, in the last 10 to 15 feet of each channel the air temperature decreases. This is believed to be caused by cold air leakage into the collector.

At this point an effort was made to seal up this portion of the collector. The efforts proved beneficial but an air leakage problem still existed. This is shown by the temperature profile in Figure VII-15. Although the air temperature decreases in the last portion of the collector, the decrease is half the amount observed in the temperature profile of Figure VII-14.

Thermocouples were also installed at the exits of each channel. These are thermocouples number 12, 13, 14, 15, 6, 16, 17, 18, 19 and



COLLECTOR THERMOCOUPLE MAP

FIGURE VII-13

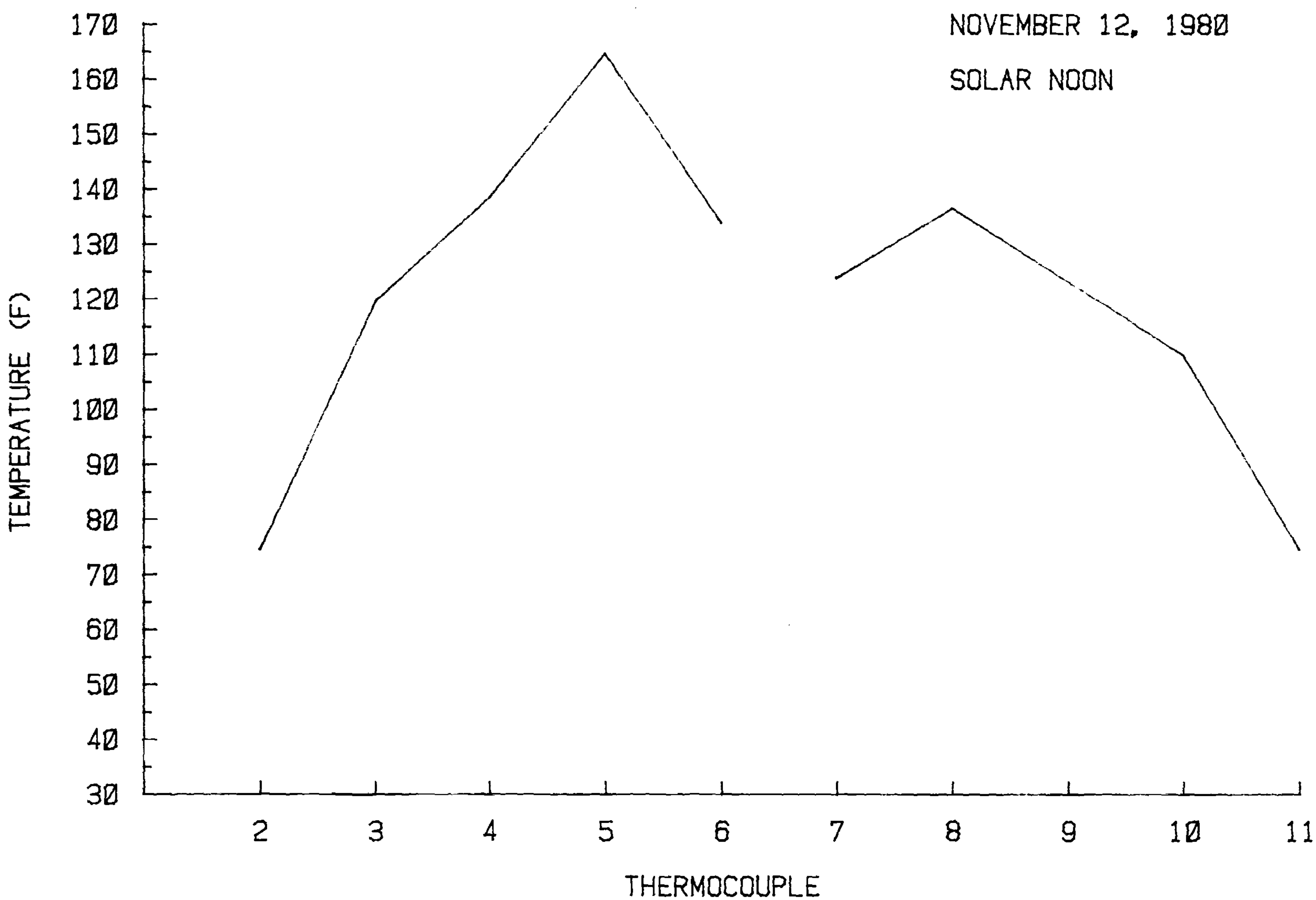


FIGURE VIII-14. Measured Temperature

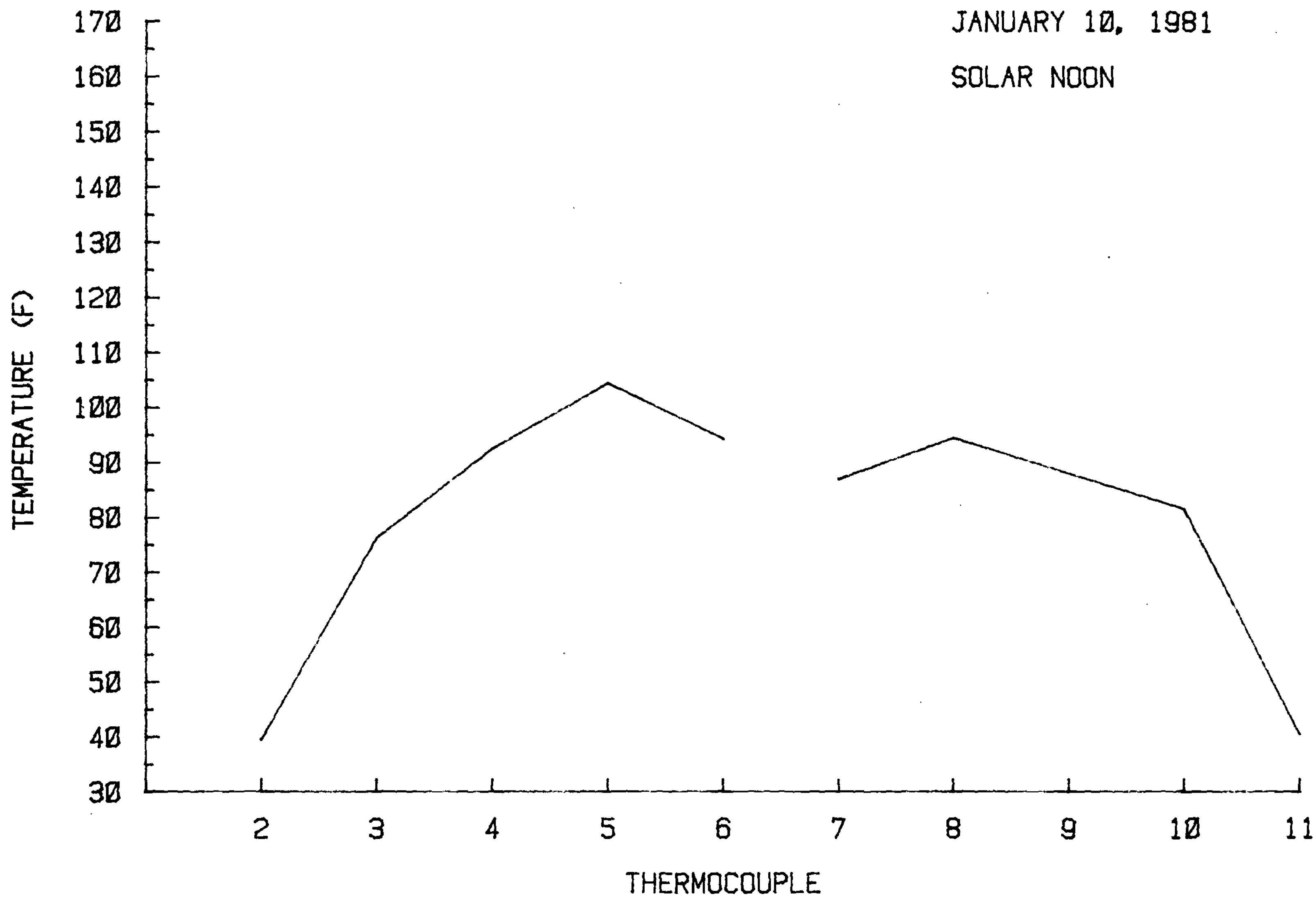


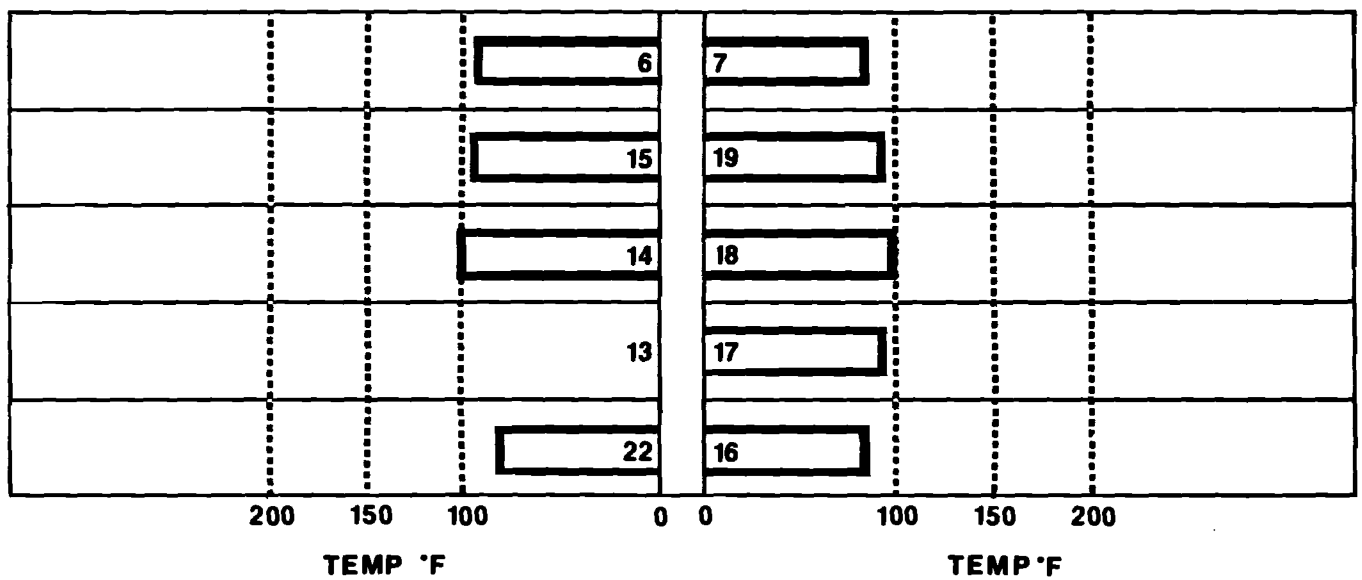
FIGURE VII-15. Measured Temperature

7. From these thermocouples it was hoped that the relative air flow between channels could be determined.

The temperatures are an indirect measure of air flow and therefore have certain limitations as discussed later. However, if the airflow in each channel were the same, the exit temperatures would be the same. Ideally, the airflows should be the same to give maximum collector efficiency. Figure VII-16 shows the temperature at the exit of each channel. This shows that all channels have about the same exit temperatures. (Thermocouple 13 gave erroneous readings and, therefore, is not shown.)

At first glance, this appears to mean that the flow in each channel is roughly the same. However, this may be false because air is suspected of leaking into the collector. As shown previously, air leakage does exist and does affect the exit temperature. The more air leakage, the lower the exit temperature. The only way for the airflows to be the same is for the leakage into each channel to be the same. One way to determine whether the airflow is the same would be to install thermocouples along each channel. From this, a channel temperature profile could be established.

Another concern with air collectors is dust and dirt coating the absorber surface. As the dust collects on the absorber surface, the solar absorption decreases. This decreases the collector efficiency which reduces the heat input to the house. Dust can settle on the absorber because the air flows between the absorber and the glazing. One solution to this problem would be to circulate air across the back



THERMOCOUPLE LOCATIONS DENOTED BY THEIR NUMBER

FLOW CHANNEL EXIT TEMPERATURES

FIGURE VII-16

side of the absorber. However, this is not feasible on the present system so a filter was installed on the collector inlets.

Another cause of dust on the absorber is backflow of house air. During the collector rebuild, the old absorber surface was noted to have a large concentration of dust around the plenum. This was believed to be caused by warm house air backflowing into the cold collector at night. The data from this winter confirmed this suspicion. This data showed that the outlet duct temperature remained at roughly the same temperature as the house temperature. The only way for this to occur, is for the warm and dusty house air to flow into the collector by natural convection. There, the dust in the air apparently settles out on the absorber surface.

Instrumentation Problems

During the first part of last winter, only 12 sample/hold integrated circuits (IC's) were installed in the data acquisition system. This was due to budgetary constraints. However, 14 more sample/hold IC's were on order from Analog Devices and were received in December, 1980. Twelve of the 14 sample/hold IC's were installed in the data acquisition system in December, 1980, and the other two were kept for spares.

One of the 12 sample/hold IC's installed in December appears to have been defective. This one defective IC affected the readings on the other 23 sample/hold IC's. Consequently, data stored on the cassette tape after the last 12 IC's were installed is invalid. This does not mean that all the information was lost after this point. Instead, the data must be read off the paper tape from the Esterline-Angus recorder which was used for backup purposes. In the future, data will be analyzed each time a cassette tape is replaced to prevent this problem from occurring again.

Economic Analysis

An economic analysis of the Villa Rica solar heating system has been performed, based on the 1980-81 fuel savings and an estimated 1981 construction cost. Four computations commonly used for solar energy systems were performed. They included:

- capital cost per installed million Btu of annual capacity,
- after-tax simple payback,
- net present value of the system, and
- the life cycle cost of the energy displaced by the solar energy system.

The results of the analysis are:

- a capital cost of $\$400/10^6$ Btu of annual capacity,
- a simple payback of 10.4 years,
- a net present value of \$-3593, and
- a life cycle energy cost of $\$18.30/10^6$ Btu.

The methods and assumptions and methods are discussed below.

The economic analysis is based on 1) a measured 1980-81 propane savings of 308 gallons, 2) a measured 1980-81 electrical usage of 356 kwh, and 3) an estimated 1981 construction cost of \$11,320. The average fuel costs were assumed to be 60¢/gallon ($6.52/10^6 Btu) for propane and 4.5¢/kwh for electricity. The 1978 construction cost was inflated at 10% per year and $1700 was added for the steel absorber surface that was added during the collector rebuild. Other financial assumptions were also made. All of the assumptions are listed in Table VII-2.

The capital cost per 10^6 Btu is simply the initial system cost divided by the Btu content of the displaced propane fuel. The simple payback and life-cycle-cost analyses were based on the following equation.

> System Cost = Initial Cost - Investment Tax Credit + (1-Tax Rate)(-Fuel Savings + Operating Cost + Maintenance Cost) - (Tax Rate x Depreciation) - (Tax Rate x Interest Cost)

The net fuel cost was inflated at the fuel escalation rate. The maintenance cost was inflated at the general inflation rate. For the life-cycle-cost analyses, each annual cash flow was discounted to its present value at the discount rate. The cash flows were not discounted for the simple payback computation. The analyses included four income tax effects: regular and solar investment tax credits, effective cost reduction for fuel and maintenance costs, tax savings generated by depreciation, and tax savings generated by interest payments.

The life-cycle-cost of energy from the system of $18.30/10^6 Btu must be compared to the life-cycle-cost of fuel, not the current fuel cost. The life-cycle-cost of fuel can be obtained by multiplying the current fuel cost by a factor from Table VII-3. For example, for a

Table VII-2
Assumptions for Economic Analysis of Solar Heating System

System Cost	\$11,320
Investment Tax Credit (25%)	\$ 2,830
Declining Balance Depreciation	2 x straight-line rate
Depreciation Life	5 years
System Life	10 years
Maintenance Cost	\$25/yr
Percent Financing	100%
Loan Cost	15%
Effective Incremental Tax Rate (Fed 21%, State 6%)	26%
Propane Savings (@ 60¢/gal)	\$185/yr
Electric Operating Cost (@ 4.5¢/kwh)	\$16/yr
Fuel Escalation Rate	20%/yr
General Inflation Rate	10%/yr
Discount Rate	15%/yr

Table VII-3
Life-Cycle-Cost Factors for a 10 Year System Life

Discount Rate	Fuel Escalation Rate .15	.20	.25
.12	1.16	1.49	1.92
.15	1.00	1.27	1.63
.20	0.80	1.00	1.26

fuel escalation rate of 20% and a discount rate of 15%, the life-cycle-cost of fuel equals $\$6.52/10^6$ Btu x 1.27 or $\$8.30/10^6$ Btu.

The results of this analysis indicates that this solar heating system is not a favorable investment for the given assumptions. Certain factors might make the investment favorable in the future. The system performance could be improved by design changes and changes in the distribution system. In a new installation using an integral collector design, some of the collector costs could be assigned to the building cost (such as the glazing replacing the roof). Also, fuel cost could rise at a higher rate than was assumed in the analysis.

Farmer's Reaction

Mr. Waddell was pleased with the operation of the system. The new controller solved one problem that concerned him. The old controller had occasionally caused cold air to be blown into the house from the collector. Mr. Waddell has been most cooperative throughout the demonstration program. He plans to operate the solar heating system again next winter.

Conclusions

The major problems observed during this demonstration program include:

1) collector fouling with dust,
2) material degradation,
3) fan reliability, and
4) collector leakage.

Each of these problems should be an important design consideration for a solar energy system to be used on a growout house.

Dust is a continuing problem. Even filtered, outside air will eventually foul the absorber surface. The most likely solution to this problem is to flow filtered outside air on the back side of the absorber surface and to use a damper to prevent back flow through the collector. This may significantly raise the cost of a retrofit installation. It should have less impact on the cost of a collector that is integrated into the roof surface.

Materials must be carefully selected and properly installed to reduce the rate of degradation. This includes even small items such as fasteners. The design should minimize the exposure of wood to the elements and protect it with paint where exposure is necessary.

Problems have been encountered with the fan shaft, pulley, and bearings. The fan runs continuously for hours, pumping air at temperatures as high as 150°F. In specifying a fan for a solar heating system, it should be established that the fan will withstand this service.

Collector leakage appears to be effecting the system performance. It should be recognized that the tolerances involved with a site built collector on a growout house can be quite large. These large tolerances should be considered in the installation details. Large overlaps, various types of sealants, and other techniques can be used to minimize the leakage in a site built collector.

Future Work

Work will continue on the Villa Rica demonstration project during the coming fiscal year. The objectives will be completion of the data reduction, instrumentation improvements, and continued performance monitoring. All of the data collected during the previous winter will be analyzed. Possible instrumentation improvements include a fan-on indicator, brooder-on indicators, and continuous air flow rate measurement. Some level of performance monitoring will be carried out during the 1981-82 winter.

REFERENCES

1. Atkins, Dale, et al, Georgia Poultry Industry Research, Final Report for Project A-2204, Georgia Institute of Technology EES, TAL, Atlanta, Ga., January 1980, pp.27-40.

2. Atkins, Dale, et al, Georgia Poultry Industry Research, Final Report for Project A-2464, Georgia Institute of Technology EES, TAL, Atlanta, Georgia, August 1980, pp.25-56.

3. Telephone conversation with William Wilhelm of Brookhaven National Laboratory on October 20, 1980.

4. Telephone conversation with Charles Allen of ICI Americas, Inc. on October 14, 1980.

5. Conversation with William Wilhelm.

SECTION VIII

COMPUTER APPLICATIONS

by L. J. Moriarty, R. M. Lamade, and J. L. Clark

Introduction

Over the past few years the use of computer systems in the poultry industry has dramatically increased. This increase can be attributed to several factors: the increasing mechanization and automation in processing and producing operation, the continually decreasing cost/performance ratio of computer systems, and (probably most importantly) an increasing awareness on the part of producers, processors, and equipment manufacturers of the capabilities of computer based process control and management information systems in poultry applications.

The poultry industry, an industry characterized by high volume, low profit margins, and subject to many variables affecting profitability is a "natural" candidate for the application of computer based control systems. However, even with the increasing number of computer systems being installed the potential applications of computers in the poultry industry is still in the early stages, with the full impact of computerization yet to be felt. In all likelihood though, within the next several years the use of computers in the poultry industry will significantly change the nature of both processing and producing operations. The purpose of this report is to provide information on computer systems presently available, systems under development, and on promising concepts not yet under development.

Computer Uses In Producing Operations

In the past decade or longer, the Georgia poultry industry has had its entire organizational structure synthesized into its present form in which most poultry farms are directly associated with the poultry integrators. The resultant industry is one which is rather closely controlled, but one in which there is an increasing need for the flow of information through communications systems.

One of the ways for this flow of information to occur is through the use of mini-computers interconnected with a central computer via telephone lines. Information can flow in either or both directions in such a system, keeping many people informed.

In discussing small computers, the term "mini-computer" is used herein to mean both the minicomputer and the microcomputer, and also to mean the special units developed from either of these.

From a physical standpoint, the farm located minicomputer can be tied into the farm telephone system much the same as an extension telephone. The unit itself can be activated by a central computer to turn it on, receive information, and turn the interconnect circuit off at the end of the transmission. The unit can be manually activated by the farmer to read out information received, to engage in a two way transmission with the central computer, or to provide self contained computational assistance.

The central computer, referred to above, can be a county computer, an area computer encompassing several counties, or an integrator's computer. The central computer can also be linked with the county computers in other area or other integrator computers through a computer at the State capital, in the Department of Agriculture or in the Engineering Experiment Station. The State computer can be linked with a computer at the Department of Agriculture in Washington.

The overall network is dependent upon the type of computer system set up in Georgia. Some of the decision areas involve financing not only the State and county computers, but also the farm computers. Inasmuch as there can be value realized by both the State and the integrators, a combination financing plan involving both of these groups would be best.

From an information standpoint, quite a bit of data generated through a system of this nature would best be made available to all the poultry farmers of Georgia. This means instituting a viable data bank at the State level that is available to all farmers and to all county extension agents through the computer system. Data should not only be available from a dissemination standpoint, but certain data that is generated constantly should be fed into the data bank on a more or less continuous basis.

It will be apparent, once a system of this nature is started, that other farm areas will want to use it. Some of these will be the dairy farms, the pig farms, and probably all the Georgia farmers. The homemaker on the farms will be using the system to obtain information on homemaking, etc. In short, once it is started, it will find a very important niche in the farm operation.

Two different kinds of computer operations are now going on in other states that are worthy of discussing here. First, in Kentucky, currently a low cost system is being test run in two counties. There are 100 farms in each county on the system. Project Green Thumb, as it is called, uses an inexpensive home information terminal (HIT) which interfaces with a regular TV set for display of the information received. The HIT is tied in through the telephone system with a county computer which is in turn tied in via the telephone system with a larger computer at the University of Kentucky in Lexington. Currently, information is being received by the farm families on the weather, commodity prices, home economics tips, and other useful items.

The HIT has a 16 key array that is used to enter data that will instruct the county computer what data should be sent and to send the county computer data if requested.

Utilizing the features of automatic dialing, automatic answering, a full keyboard, data compression during transmission, and password requirements, a system such as Green Thumb could be used in many ways on the poultry farm. It can be seen that being linked to the integrator would allow the transmission of information to and from the integrator concerning the daily operations of the poultry farm. Through a telephone linkup of computers, it would be possible to receive maintenance and repair instructions on farm machinery directly from the manufacturer. There are cases of complex, computer controller machine tools being repaired by telephone connection with the master computer at the machine tool manufacturer's plant. Such uses of computers are becoming more commonplace daily.

At Pennsylvania State University, a seven year program has been performed analyzing various on-farm management practices with cost factors. The work has been performed with Pennfield Corporation, a Lancaster, Pennsylvania firm, as the primary industry cooperator. Pennfield is a multi-house poultry farm which has a processing plant nearby. Starting with a complete inventory of the entire operation, the variable factors have been measured over a period of time. By using several years performance for data measuring purposes, meaningful comparisons have been made.

With the poultry farm system here in Georgia, it would be more meaningful to work through an integrator with a number of cooperative poultry farmers. The kind of data needed in a study like the one at Penn State includes the floor space per bird, feeder space per bird, waterer space per bird, hauling distance in miles per load, off feed time in minutes per load, types of houses, litter cleanout schedule, lighting systems, ventilation systems, cleaning procedures, overage weight per bird when marketed, pounds of poultry meat graded "trim", pounds of poultry meat graded "bruise," numbers of condemnations, and reasons for condemnations. Setting up such a system would not only provide finite data for the management of the integrator, but would start building a data base to aid all poultry farmers and integrators in Georgia, if the cooperating integrator would allow the use of the information.

In such a program, a number of the poultry farms would transmit data on a daily basis to the integrator. This information would be fed into a larger computer for long range storage and use in following each flock through the system. Such data transmission also affords the integrator other options such as identifying trends, as they commence, that could lead to problems. (For example: these could be disease problems, etc.). Also, by keeping a close watch on the weather, warnings could be sent out to possible affected areas regarding storms, tornadoes, etc.

The poultry farmer can benefit from the use of the computer in his operation. Already some 7500 U.S. farmers are estimated to have purchased a personal computer to aid in the management of their farms, according to a recent newspaper article listing.[1] Further, predictions indicate another 172,500 farmers will buy computers within six years.[2] Most of these users have developed their own programs. Almost daily, more programs for farm use are appearing on the software market. There are now quite a few software firms - individual people up to large firms - which will write a program, for a fee, for anyone who wants one. The big problem today is letting farmers know about the available programs and where to get them. "Successful Farming" is now starting a newsletter to get this kind of information out to farmers.[3]

Computers in the mini-computer size are now available on the open market starting at about $500. Depending on how complex an operation is desired, a reasonable unit can be put into operation for as little as $2500 but can go higher than $13,000.

If systems are going to be developed, reduced prices and proper features can be obtained in a group of units such as the over 200 units used in the Project Green Thumb operation. By standardizing the make, and buying in large quantities price concessions are available. But if a number of poultry farmers individually purchase units, the price becomes quite high. The poultry farmer will have a computer sooner or later just like a number have gone to using calculators. The computer, when used solely as a farm tool, is quite difficult to justify costwise. But, when the option of telephone tie-in with a central computer is available, the uses more than double, helping with the cost justification.

There are a number of advantages of the computer for the poultry farmer. If he has the outside connection (via telephone) with the count and/or integrator computer, and the use of the computer on the farm he can:

- o Receive State wide or region-wide information on weather, crops, marketing of crops and livestock, home economic tips.
- o Receive information from the integrator on feed mixes, problems encountered by other poultry farmers together with solutions to the problems.

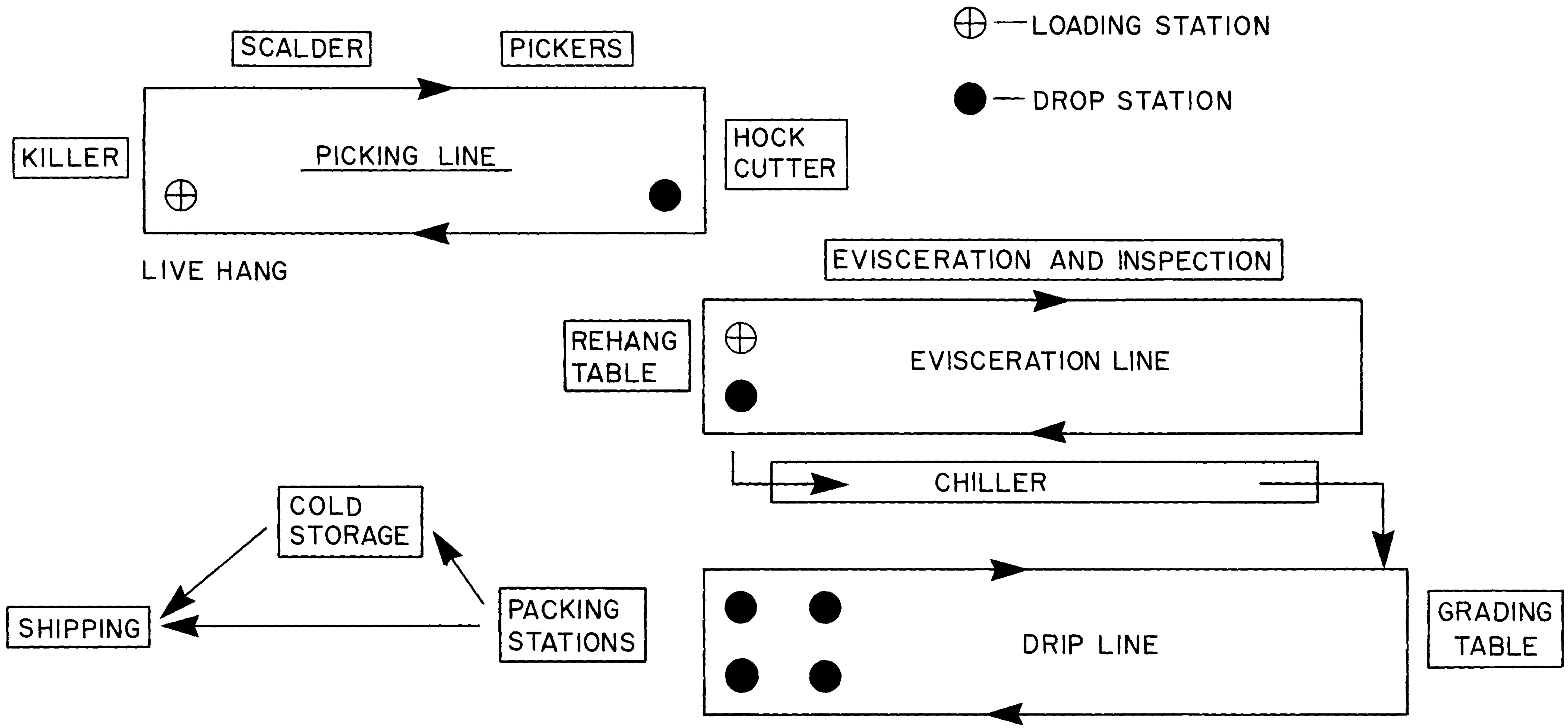
- o Keep his integrator informed on the status of his flock in such areas as feed consumed, water consumed, problems encountered, dead chicken count.
- o Access data storage at either the integrator, state, county data bank on a specific problem.
- o Transmit special weather information.
- o Control the physical operations of the poultry houses.
- o Maintain accounting data on all farm operations. Keep track of expenses, income, bank payments, etc.

The net result of such a network or system will be the transmission of information in both directions to and from the poultry farmer helping him in his operation of raising poultry. The overall benefits are not directly measurable, but should reflect in better poultry production through fewer problems.

Computer Applications in Processing Operations

Although data processing computers have been used in poultry processing plants for many years in such applications as payroll processing, accounting, and order processing, the use of computers to control production processes in the plant is relatively new. To better understand the potential applications of computers in the poultry processing industry, a description of the processing operations is given in the following section. Those readers already familiar with processing operations may wish to skip over this discussion.

Figure VIII-1 shows in simplified form the major steps involved in poultry processing. Processing starts at the live dock where the



PROCESS FLOW DIAGRAM

FIGURE VIII-1

birds are brought in from the farm and ends at the shipping dock where the processed poultry is shipped out.

At the live hang station the birds are removed from their cages and hung by their hocks (feet) on an overhead conveyor line. This conveyor line, called the picking line, is one of several overhead conveyors used to transport the birds through the various processing steps. From the live hang station, the birds pass through the stunner, an electrified salt-water filled trough designed to incapacitate the bird. The birds' throats are slit in the killer and from there they go into the scalder, a vat filled with hot water that serves to loosen the feathers so they can be removed by the picker. The picker is a machine containing a large number of rotating rubber fingers that remove the birds' feathers by literally beating them from the bird. After the picker the birds pass through the hock cutter which removes the birds' feet, causing the birds to drop off the picking line onto the rehang table for processing on the eviscerating line. The birds are hung on the eviscerating line and from there they undergo a series of inspections and processing steps. USDA inspectors check for causes of downgrading or condemnation. It is also on the eviscerating line where the internal organs are removed. At the end of the eviscerating line the birds are dropped into the chiller. The birds are in the chiller, a long tank filled with cold water, for about 45 minutes where the carcass temperature is lowered rapidly to approximately 40°F.

From the chiller the birds are graded and then hung on the drip line. Scales on the drip line weigh and sort the birds by weight, dropping them into packing bins located under the drip line. This step is important because some customers (fast-food restaurants, for example) set strict standards for bird weight. The birds are the packed into boxes and they are either immediately shipped to the customer or placed into cold storage.

Of the computer based process control systems presently in operation in poultry processing plants, the majority have been installed as replacement systems for mechanical sizing scales used on the drip line. The function of the sizers is to sort birds by weight, dropping birds within a predetermined weight range into bins located under the drip line. A typical mechanical sizing system consists of a balance-beam weigh scale installed on the drip line, an air-actuated tripper mechanism located down the line of the weigh deck, and special shackles designed to operate with the weigh deck and tripper mechanism. An electronic sizing sytem, on the other hand, consists of a weigh deck using a load beam weighing cell, a number of electrically operated trip mechanisms, special shackles and a small computer. Because a single computer and weigh deck can operate many trippers, the cost savings for large system can be significant. For example a 15 drop electronic scale sells for about $20,000 while a mechanical system would cost over $60,000. In addition to the cost savings, there are other advantages to electronic scales including:

- o Accurate weighing at high line speeds. Mechanical scales will not operate well at line speeds over 140 birds per minute, but electronic scales are in operation on lines operating over 170 birds per minute.

- Convenient and quick changing of the scale weight limits. Changing the weight limits on a mechanical scale requires physically accessing to the scale balance weights, while with an electronic scale the new limits are simply entered using a key pad at the controller.

- Acquisition and display of production parameters including count and weight totals for each drop, line speed, and hanging weight. This information, which a mechanical scale cannot provide, can be sent to a larger central computer for integration into a plant wide computer system.

- Ability to add special features such as preset drop cut-off, expanded range operation, and gizzard stuffing monitoring.

Another computer based weighing system that has been very successful is the master carton weigher. This system monitors and records the weight of each master carton of processed poultry as the carton is packed. Box tare weight, as well as the weight of added ice (which depends on shipping distance) is automatically taken into account. The operator loads poultry into the carton until the computer display indicates that the correct weight has been loaded. The operator's identification number and the weight deviation of the packed weight from the desired weight is logged and stored in the system computer. The carton serial number and weight are also printed on the carton and at the computer console. At any time during the shift the supervisor can access the computer and display in a semi-graphical form the operator's performance. An incentive pay plan could easily be implemented with this system, with the operators showing the least deviation from the desired box weight being paid more. By serial numbering the boxes and recording and storing box weights, erroneous shortweight claims from the customers are greatly reduced. A master carton weighing system costs about $20,000 and the payback has been estimated to be about three months.

Bird counting systems, are also coming into fairly widespread use in processing plants. These systems are very rudimentary though, being for the most part a collection of stand-alone devices with readouts that are periodically read manually. There is however, a Canadian processor who has attempted to integrate a large number of separate counters into a single central system with automatic data logging and central display. However, to date this system is not operating.

With the price of whole birds presently being depressed, processors are looking into further processing to increase profit margins, as well as to provide a hedge against fluctuation in whole bird prices. The popularity of "fast-food" chicken sandwiches has sharply driven up the price of breast filet meat, making further processing very attractive. Because fast-food restaurants place strict specifications on the weight ranges they will accept (usually weights must be accurate to within .01 pounds), there is a pressing need for an automated method to accurately weigh and sort chicken parts. Several attempts have been made to use general purpose commercial weighing and sorting systems, but these efforts have been unsuccessful. There is, however, a specially designed parts weigher available developed by an poultry equipment manufacturer with help from Georgia Tech, that will accurately weigh and sort poultry parts at speeds up to 125 parts per minute. This machine requires only one operator to load the parts, eliminating several employees required for manual sorting.

A parts weigher is in operation in a further processing plant in Georgia. This processor estimates that this machine has nearly doubled his productivity, resulting in a three month payback for the equipment.

With a few modifications the parts weigher can be used in other applications. A North Carolina duck processer has installed a parts weigher with special buckets to weigh and sort whole ducks. With some programming changes the parts weigher could be used to pack cartons, automatically selecting parts so that the packed carton weight would be within specified weight limits.

Parts weighers also work very well with automatic deboning machines because the deboners presently available provide the best yield with uniform size parts. If, for example, a processor has three automatic deboning machines, he can use a parts weigher to sort parts into three weight ranges, light, medium, and heavy. He then can adjust his deboners to provide the best yield for a given weight range, resulting in a greater overall plant yield.

Electronic Yield Evaluation

For the past three years the Applied Engineering Division of Georgia Tech's Technology Applications Laboratory has been working on developing a computer-based system to monitor and evaluate poultry processing plant eviscerating line performance. References 4 and 5 contain a description of the system and the work that has been done during the first two years of the project. The following discussion describes the work done this year, the efforts made to publicize and develop interest in the project, the present status of the project, and plans for the future.

An important milestone was achieved this year when the system came on line and became fully operational. During the time the system was in operation a large amount of data was collected, and valuable operating experience was obtained. Mar-Jac management personnel are satisfied with the performance of the system and they have indicated that they are very interested in having the system permanently installed in their plant.

There are, however, several technical problems that need to be resolved before the system is ready for general use. The single most difficult problem involves developing a scale mechanism that will operate reliably and accurately and yet be compatible with the eviscerating line machinery. The scale deck used with the prototype system is shown in Figure VIII-2. This scale deck is similar to scales used on drip lines, and while it worked well enough in some locations, there are other locations on the eviscerating line where

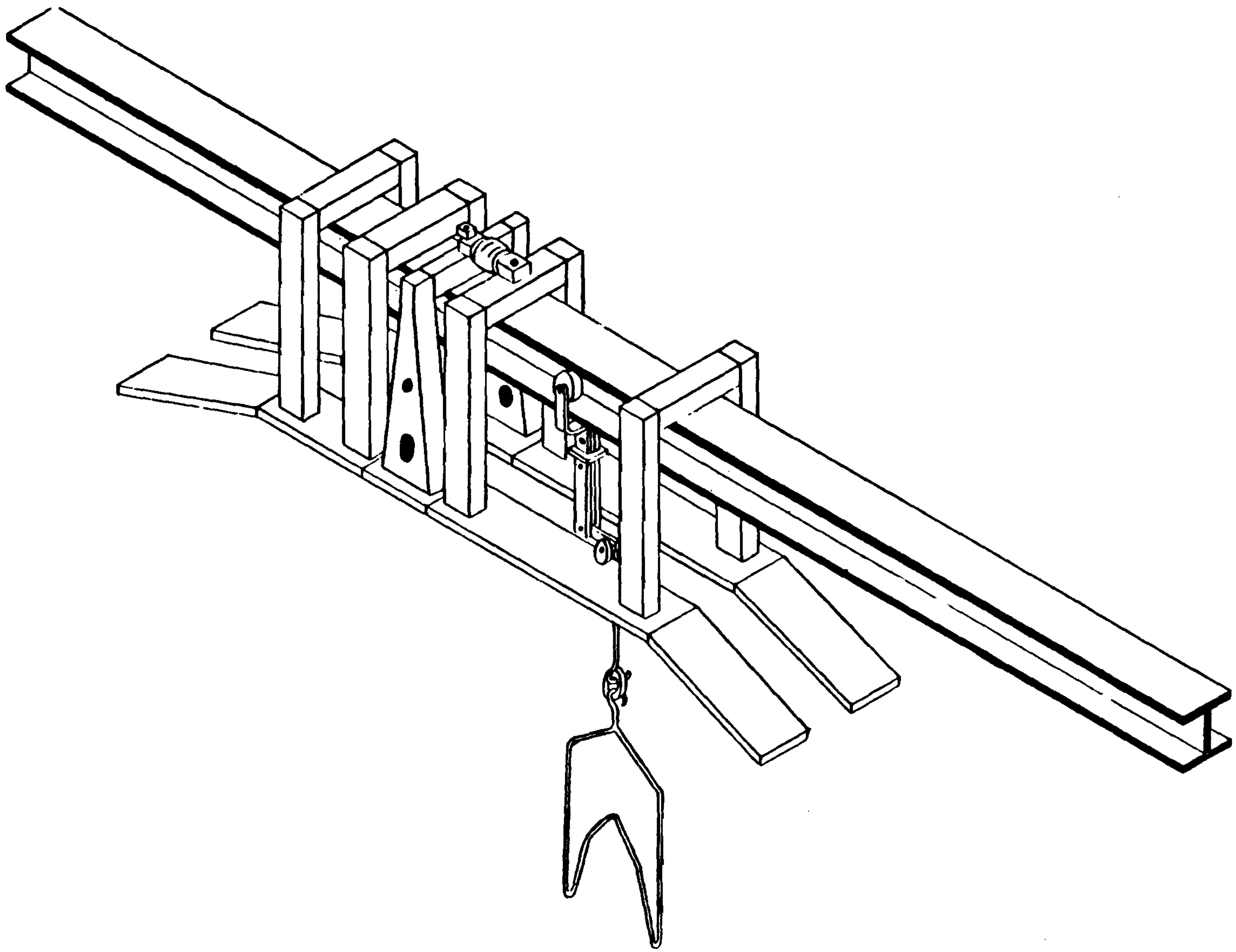


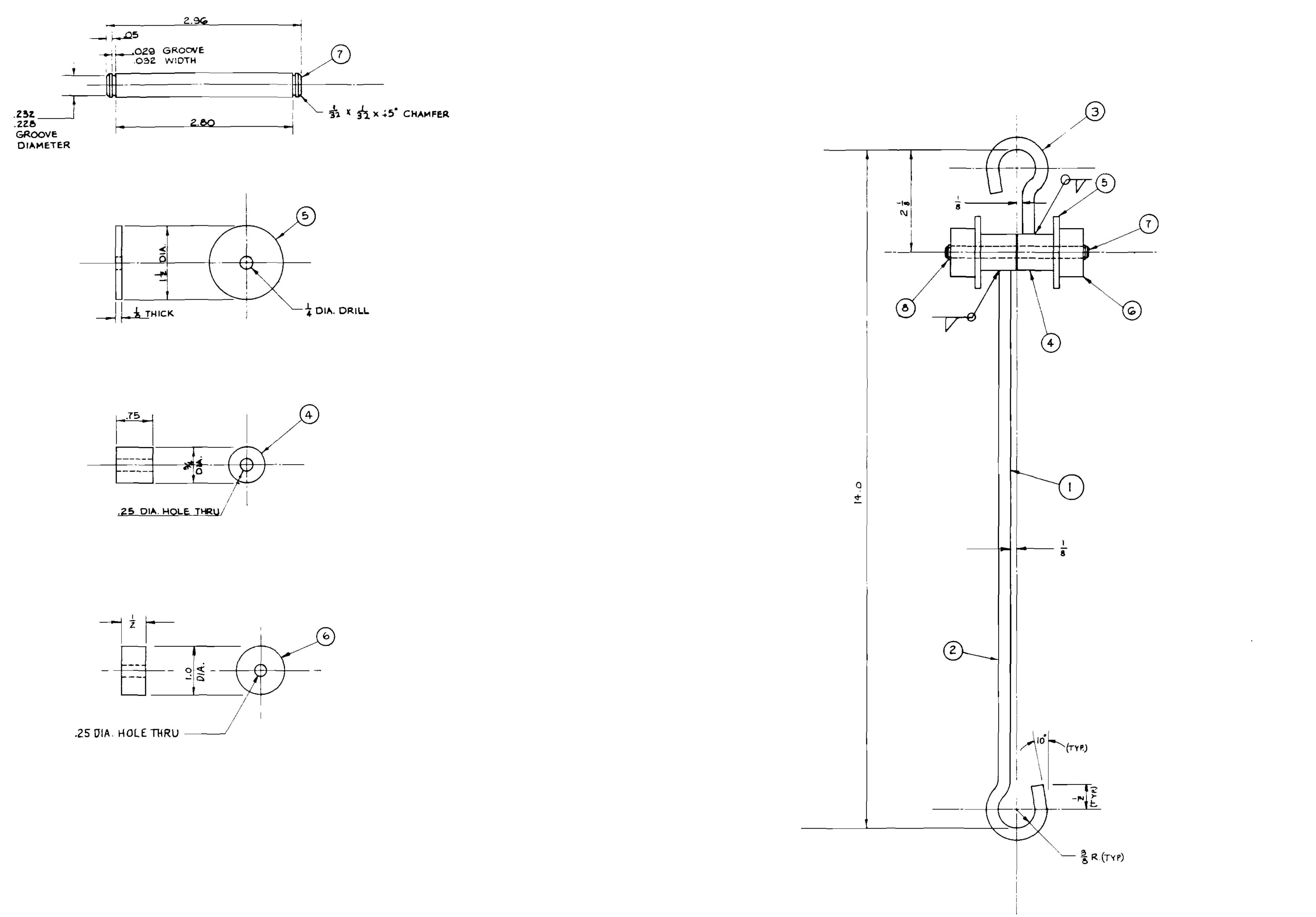
FIGURE VIII-2 WEIGH SCALE

the scales work less satisfactorily. In addition there were problems with the shackles tracking through the Pritchard helical line dividers used by Mar-Jac. Occasionally a shackle would hang on the line divider, or a bird would be turned 180 degrees.

A substantial amount of work was done to develop a shackle that would track through the scales well, but still operate with the line dividers. The first effort led to the non-symetrical shackle shown in Figure VIII-3. This shackle was inexpensive and worked very well with the line divider, but unfortunately did not provide scale weights of sufficient accuracy. The yoke type shackle shown in Figure VIII-4 was then tried, and this shackle design proved to be acceptable. The yoke shackle gives very accurate weight readings, and works reasonably well with the line dividers. Occasionally a shackle will hang in the line divider, but with the limited number of yoke shackles in service this was not a major problem. However, if the eviscerating line were to be fully populated with the yoke style shackles, the problems with shackle hang-ups might prove to be unacceptable.

Initially 25 yoke style shackles were installed, but analysis of the data indicated that the sample size was not large enough to obtain meaningful data. Twenty five more shackles were fabricated and installed, bringing the sample size to nearly seven percent, which resulted in much better data. The sample size issue however turned out to be irrelevent because every processor interested in the system indicated that they would want to weigh and count every bird.

Another problem with the drip line style weigh deck is that it occupies too much space on the line. The processing station on the



QTY	ITEM	P/N	DESCRIPTION	NOTE
2	8	5100-25-H	WALDES KOHINOOR RING	
1	7		$\frac{1}{4}$ DIA. SHAFTING X 3 LONG SST	
2	6		1" DIA. ROD X $\frac{1}{2}$ LONG SST	
2	5		$\frac{1}{8}$ PL X $1\frac{1}{2}$ DIA. SST	
2	4		$\frac{3}{4}$ DIA. ROD X $\frac{3}{4}$ LONG SST	
1	3		$\frac{1}{4}$ DIA. ROD X $2\frac{1}{4}$ LONG SST	
1	2		$\frac{1}{4}$ DIA. ROD X $12\frac{1}{2}$ LONG SST	
-	1		SHACKLE ASSEMBLY	

FIGURE VIII-3 ECCENTRIC SHACKLE DESIGN

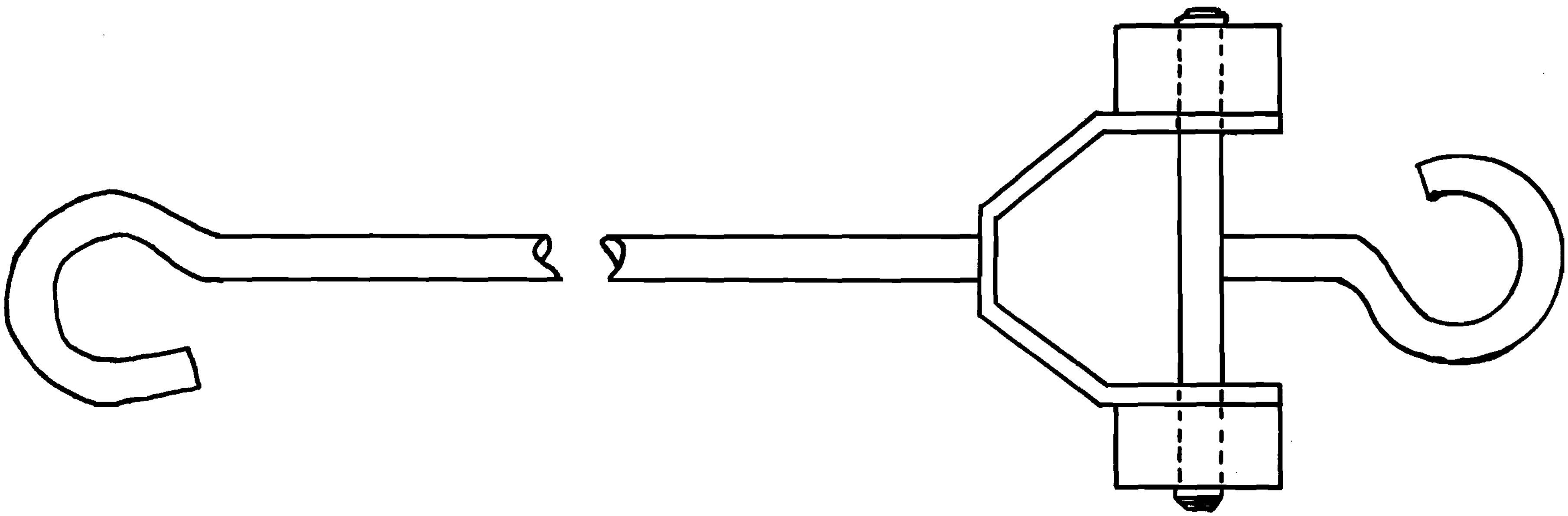


FIGURE VIII-4 YOKE STYLE SHACKLE

eviscerating line are typically very close together with very little space between stations for the installation of a weigh scale deck. The long lead in and lead out rails of the drip line scale require over three feet of line space, requiring costly and difficult line modifications at some scale locations. The rehang station scale would be especially difficult to install.

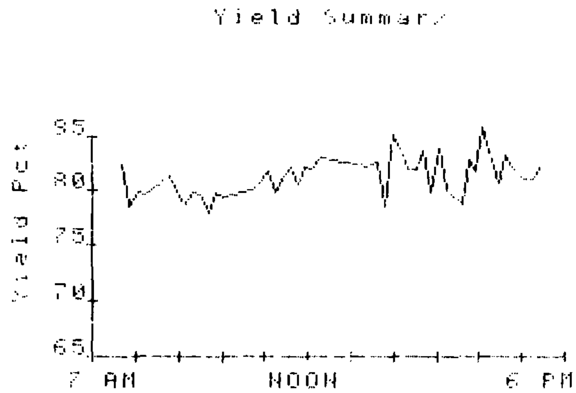
The answer to this problem is to design a scale that would operate by directly lifting the shackle. Several equipment manufacturers including Sterling Controls and Chick-Weigh have been working on developing such a scale, but to date no direct lift scale is commercially available. The design problems do not seem to be insurmountable though, and the development of a direct lift scale should be relatively straightforward.

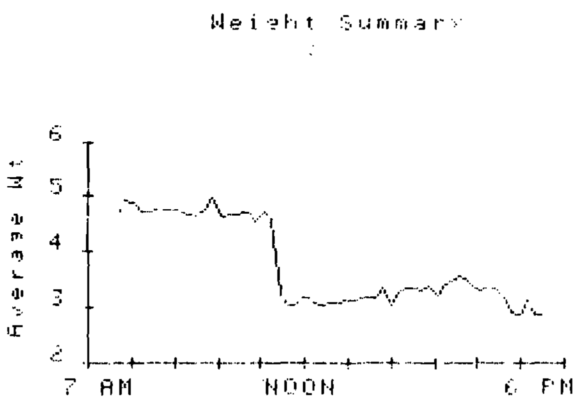
The computer and electronics subsystems were much easier to develop than the scale mechanism. Except for some software improvements and updates, the computer and electronics interfaces have been unchanged and have operated remarkably trouble free for the past several years. In fact there has been only one computer failure during the life of the project, and that occurred when the cartridge tape drive on the system controller failed.

The software changes and improvements largely involved developing programs to interface the system controller to an HP-85 computer acquired by the laboratory. The plan was to use the system controller to operate the system and collect the data, then transfer the data to the HP-85 computer for later analysis. Prior to acquiring the HP-85

DATA SUMMARY FOR 02/20/81

AVERAGE YIELD	81.3	%
AVERAGE WEIGHT	3.73	LBS
TOTAL WEIGHT	123013	LBS
BIRDS PROCESSED	31433	
BIRDS REMOVED	1567	





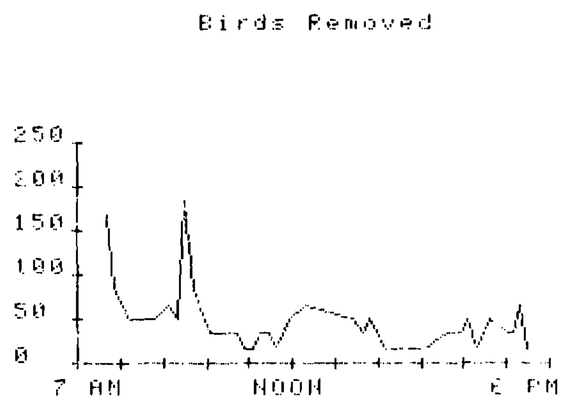


FIGURE VIII-5 TYPICAL DATA SUMMARY

efforts were made to establish a telephone data link between the system controller at Mar-Jac and the CYBER computer located on the Georgia Tech campus. These efforts proved to be unsuccessful though because of the difficulties involved in transferring large amounts of data essentially error-free over the telephone data link.

A typical data summary is shown in Figures VIII-5. The results obtained from analyzing the data strongly suggest the presence of significant variations in the yield, with changes of over one percent in the yield being recorded. However, no correlation between yield and time of day or bird weight was found. Mar-Jac personnel were able to identify several causes of the yield variations through. They found that personnel problems, especially being short handed on the eviscerating line, caused significant yield decreases. Of course, this is information they, at least, intuitively felt to be the case; the yield system served to quantify and confirm the problems.

Several efforts were made to publicize and promote the yield system. An information packet and invitations to visit the Mar-Jac installation were sent to all Georgia Processors and the system was exhibited at the Southeastern Poultry Show in Atlanta. The May issue of the Poultry Newsletter contained an article on the yield evaluation system. Industry reaction to the yield system has been generally favorable, with an increasing interest being shown in the last several months. In addition to Mar-Jac, one other Georgia processor is seriously considering installing a yield evaluation system.

REFERENCES

1. The Associated Press, Seed is Sown for Farmers to Harvest Computer Age, Atlanta Journal, June 10, 1981.

2. Ibid.

3. Ibid.

4. Atkins, Dale, et al, Georgia Poultry Industry Research, Final Report for Project A-2204, Georgia Institute of Technology, Engineering Experiment Station, TAL, Atlanta, Ga., January 1980, pp. 41-54.

5. Atkins, Dale, et al, Georgia Poultry Industry Research, Final Report for Project A-2464, Georgia Institute of Technology, Engineering Experiment Station, TAL, Atlanta, Ga., August 1980, pg. 57-77.

SECTION IX

WASTEWATER TREATMENT IN POULTRY PROCESSING PLANTS

by G. E. Valentine Jr. & G. M. Battaglia

Introduction

During 1980 over 597 million chickens were processed in Georgia and approximately 4 billion gallons of water were used during this processing. This tremendous volume of water must be treated and the costs associated with the treatment represent a major expense to the processor. These costs are incurred through the purchase and operation of treatment facilities or by surcharges levied by municipalities receiving the untreated wastewater.

This study looked at a specific poultry processing plant. The study was divided into two parts. The first part was undertaken to characterize those specific sites within the processing plant which contributed most to effluent waste loads. The second part was the design, fabrication, and testing of a bench top laboratory model rotating biological contactor to treat the waste stream.

It was expected from the first part of the study that sites of heavy load contribution could then be changed or modified to improve their quality by reducing their load contribution. The ultimate goal would be the reduction of waste loadings on the final plant effluent.

From the second phase of the study it was hoped to gather working data on the feasibility of treating poultry processing wastes with an

RBC unit. Our goal was to determine the suitability of an RBC system for treating poultry wastes in general, and specifically if one would help reduce the pollutant loads at our test plant.

Procedure

Our test processing plant was chosen for its nearness to our analytical laboratory and because at present only minor pretreatment facilities had been installed to handle wastewater treatment. Collection times were chosen at random to gain an understanding of average daily waste loads. Grab samples were collected at the following locations: giblet tank, blood pipe, feather flume, eviseration auger, waste flume before screens, waste flume after screens and final plant effluent. Samples collected were immediately brought to the lab for BOD determination. After these samples were taken, acidification to pH_2 by HCl was done, followed by storage at 4°C until fat and solids determinations were completed. BOD, Oil and Grease, and solids determinations were determined in accordance with current water pollution control standards.

A summary of the data obtained from the physical and chemical analyses of samples collected in this study is shown in Table IX-1. The greatest concentrations of BOD can be found from the blood pipe, giblet chiller and to a lesser extent the evisceration trough. The blood pipe contained uncollected blood mixed with small amounts of water, however its flow was quite small throughout the work day in comparison to the giblet chiller and evisceration trough. Correspondingly oil and grease and solids concentrations were also

Table IX-1

Average Wastewater Characterizations for Test Plant (Reported as mg/l of Wastewater)

	BOD	Oil & Grease	Solids		
			Total	Suspended	Volatile
Blood Pipe	7,600	-	7,140	767	-
Giblet Chiller	8,850	545	10,800	2,400	2,000
Evisceration Trough	3,000	500	4,140	2,745	3,450
Waste Flume (Before Screens)	1,500	515	2,250	736	1,850
Waste Flume (After Screens)	1,475	510	1,285	608	1,100
Final Effluent	1,100	390	835	325	536

highest at these particular points in the plant. When comparing this data with that collected by Hamm,[1] in his characterization of 10 poultry processing plants, we see our test plant having much greater concentrations in almost all categories. Our average figures compare closely with Hamm's *high end figures. This indicates that there exists a great potential for improvement in waste control reduction in the study plant.

Although the pipe leading from the blood tunnel was high in BOD, the extremely small flow passing through it makes it impractical to treat this waste stream separately. The giblet tank however, is one area where a reduction in BOD, suspended solids, and oil and grease can be reduced with minimum expense. We suggest a small holding tank with both a surface skimmer to pick up solids which will precipitate out from the quiescent horizontal flow. The grease removal should be significant due to the cold water which is normally used in the giblet tank, thus maximizing grease separation. This grease has a high market value to poultry renderers so that a short payback period on the installed equipment can be realized. This is in addition to the solids removed from the water stream that can be augered into drums and then dumped into the rendering trucks. This will eliminate an unnecessarily high concentration of solids, BOD, and grease on any treatment system installed.

Process Description of the Rotating Biological Contactor

The rotating biological contactor (RBC) is a relatively new application of the biological fixed film treatment principle. The process has been in commercial use in the U.S. since 1969. Installation capacities have ranged from less than 0.04 m^3/sec to more than 2.2 m^3/sec (1 to 500 mgd). The rotating biological reactor because of its characteristics of modular construction, low hydraulic head loss, and shallow excavation can be used as easily with new treatment facilities as with existing treatment facilities. It can also be used in a variety of configurations to upgrade the existing level of treatment. The RBC unit consists of a series of circular discs mounted on a horizontal shaft. The unit is installed in a tank so that the surface of the wastewater passing through the tank almost reaches the shaft. This means that about 40% of the total surface area of the discs are always submerged. The shaft continually rotates and a layer of biological growth 2 to 4 mm thick is established on the wetted surface of each disc. The biological growth that attaches to the discs assimilates the dissolved organic matter from the wastewater and flocculates the suspended matter for subsequent gravity separation. Part of the absorbed organic matter is oxidized to carbon dioxide and water and part is synthesized into additional biomass. The attached biomass contains approximately 50,000 mg/l suspended solids. If the biomass is removed and placed in the mixed liquor, the resulting suspended solids concentration would be 10,000 to 20,000 mg/l.[2] The shaggy growth provides a large active biological surface area, much larger than the surface area of the media. This large, active microbial population achieves high degrees of treatment for relatively short wastewater retention times. Aeration is provided by the rotating action, which exposes the discs to the air after contacting them with the wastewater. To increase treatment efficiency the media is usually divided into a series of stages. Each stage of media operates as a completely mixed, fixed film biological reactor which develops specific microbial cultures that adapt to the specific wastewater characteristics. An equilibrium is reached within each stage between the rate of biological growth and the rate of stripping biomass. The excess biomass is sheared off and maintained in suspension by the turbulance created by the rotating action of the discs. Eventually, the flow of the wastewater carries these solids out of the system and into a clarifer, where they are separated.

The RBC process offers many advantages which make it an especially attractive treatment system for poultry processing wastewater.

1. Low energy requirements

   A 30% savings in power can be effected when compared to an activated sludge process. With energy costs soaring, this is a major benefit of the RBC process.

2. Simplicity of operation and maintenance

   The system operates without sludge or effluent recycle thus requiring less plumbing, pumping, and metering. Also a smaller vessel is required over conventional treatment systems. Chemical requirements are minimal or none. The motor that rotates the media is the only moving part and requires little maintenance. The low mechanical maintenance requirements combined with the low power consumption contribute significantly to overall "life cycle" cost effectiveness.

3. Flexibility

   Because of its modular construction, low hydraulic head loss, and shallow excavation, it is possible to incorporate RBC process equipment into many existing treatment facilities with little or no change in the existing facilities. It can be easily modified to allow for future plant expansions, product and process variations and to achieve various levels of treatment.

4. Process stability

The RBC process is not upset by variations in hydraulic or organic loading, since the vast majority of the active organisms are attached to the media, and operate independently of the final clarifier.

5. Sludge characteristics

Clarifiers following the RBC units can be relatively small because of the low concentration and high density of the mixed liquor solids. Also any suspended BOD entering the system is rapidly bio-flocculated and settles out easily in the clarifier. Sludge dewatering costs are reduced because of the higher solids contents (2-3%) when compared to 1% for activated sludge.

6. Space requirements

Some biological treatment processes, such as lagoons and land application systems require relatively large portions of land. Often the land required for these treatment facilities is expensive or not available. The RBC requires a relatively small area because of is highly active and concentrated biomass.

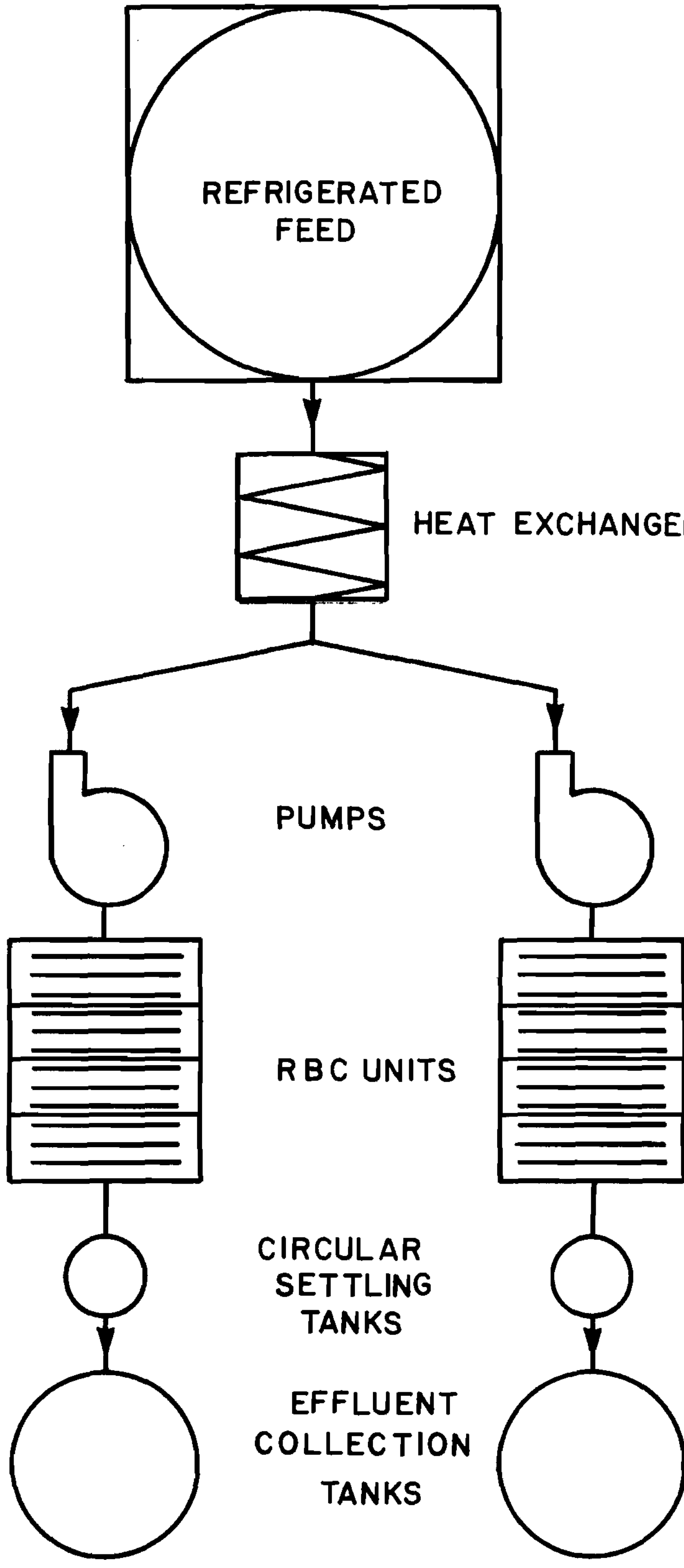
Purpose of Study

This study was concerned with identifying the capabilities of the RBC process in treating poultry processing wastewater. All biological treatment processes employed by environmental engineers are dependent upon the healthy growth and reproduction of the organisms employed. In planning waste treatment facilities bench scale and pilot plants system are important in testing the actual waste under simulated operating conditions to determine whether or not the waste in question is amenable to treatment with the proposed process. The initial phase of the study was mainly to establish the carbonaceous organic removal efficiencies of the RBC by using a bench scale unit with the feed source being the actual discharge from a poultry processing plant. Other parameters studied included suspended solids removal, oil and grease removal, COD to BOD ratio and sludge production. The ultimate purpose of the study was to produce specific data on the RBC process for the treatment of poultry processing wastewater, and thus give treatment plant designers and operators the information on which to base design and operation of the system.

Bench Scale Unit Description

The two units used in our experiment each consisted of 12 discs separated into four stages by baffles. Each baffle had two, one inch holes drilled into it to allow for wastewater flow. Each of the stages contained three plexiglass discs which were 12 inches (30.5 cm) in diameter and 0.25 inches (9.635 cm) thick. The total effective (wetted) surface in each unit was 17.8 ft^2 (1.65 m^2). One 1/15 hp AC/DC electric motor was used to drive both units whose shafts were connected with an in line flexible coupling. A gear reducer in conjunction with a speed controller was used to maintain the rotational speed at 19 rpm throughout the test period. The system is depicted in Figure IX-1.

The water level in the units was held at a constant depth so that approximately 40% of the discs were submerged. The flow path of the wastewater was perpendicular to the face of the discs. A variable speed Cole-Palmer Masterflex peristaltic pump with two identical pump heads was used to pump the wastewater to the individual units at a controlled rate. The rate of flow was measured using a graduated cylinder and a stopwatch. The water leaving the RBC entered a circular settling tank (6.5 inch diameter) to allow the settleable



Overhead Schmatic of Bench Scale RBC System

FIGURE IX-1

solids to be separated. The overflow from the settling tank went to a graduated collection vessel from which composite effluent samples were taken.

Wastewater was collected in two 50 liter polyethylene carboys every two to three days at the processing plant, then transported directly to the laboratory, and stored at 4-8°C. The wastewater was collected at the plant at the point where it discharged into the municipal sewer system. The wastewater used was essentially a grab sample collected during plant operating hours and not necessarially representative of the total water leaving the plant during a 24 hour period. Prior to the point of its collection the wastewater had first passed through a drum screen where large solids were removed, then through a microscreen where finer particles were removed and finally through a grease tank where some of the floatable and settleable material were gravity separated.

Experimental Procedure

The RBC's were initially operated in series with complete recycle of the poultry processing wastewater. The only seeding done was during the first week with small samples of moist soil collected outside the laboratory. When a good stable growth of organisms was established on the discs, a normal flow through pattern was initiated. At steady state the initial stages of media, which receive the greatest concentration of organic matter, developed cultures of filamentous and non-filamentous bacteria. This growth was relatively thick (4-5mm) and had a medium brown color. As the concentration of organic matter decreased in subsequent stages, higher life forms including nitrifying bacteria and other microrganisms began to appear. The growth on the latter discs was noticably thinner and had a translucent grayish appearance.

The environmental conditions; pH, dissolved oxygen and temperature, of the units were monitored stage-by-stage. A Fisher Accumet Model 630 pH meter equipped with an Orion combination gel filled pH probe, was used to determine the pH in each stage and of the feed. A YSI Model 54A oxygen meter and probe was used for the dissolved oxygen determinations. Temperature was measured in situ for each stage of the RBC unit using a NBS certified thermometer. The Autrotrol Design Manual[3] identifies 0.3 m/sec (60 ft/min) as the most effective peripheral speed based on their operational data. The rotational speed was held constant during this study at 19 rev/min which corresponds to the suggested peripheral speed of 0.3 m/sec (60 ft/min).

Removal of organic matter was observed by monitoring the chemical oxygen demand (COD) uptake by the units. The COD samples were taken in duplicates and were analyzed by the Oceanographic International Ampule Method. The biochemical oxygen demand (BOD_5) was determined using procedure 507 from Standard Methods.[4] The COD and BOD test are both tests used to measure the pollution strength of industrial and domestic wastes. Five day BOD_5 is a widely used parameter that involves the measurement of dissolved oxygen used by microorganisms in the biochemical oxidation of organic matter. The BOD_5 measurement is significant because it is used to determine the approximate quantity of oxygen that will be required to biologically stabilize the organic matter present. The BOD_5 determination has several limitations that include the need for an acclimated seed bacteria, toxic waste inhibition, measurement of only biodegradable organics, nitrogenous oxygen demand, and a long period of time to obtain results.

The COD test is another measure of the organic matter in water, it measures the oxygen equivalent of the organic matter that can be oxidized using a strong chemical oxidizing agent in an acidic medium. Biological oxidations are seldom as complete as chemical oxidations because of the biologically resistant organic compounds and the fact that some potentially oxidizable biomass remains even at the end of long-term tests. However for a given wastewater it is sometimes possible to establish a correlation between COD and BOD values. This is very useful because the COD can be determined in 3 hours, compared to 5 days for the BOD. Because of its analytical advantages the COD test was used as the primary means for evaluating the organic removal efficiency of the RBC units in this experiment.

Suspended solids is another parameter that is generally limited by regulations regarding its discharge into the sewers or natural waterways. All solids determinations were done by the appropriate technique from Standard Methods.[5]

Many municipalities and other authorities have ordinances for the regulation of discharge of grease-bearing wastes into sewer systems or to receiving waters and use grease and oil determination for regulatory purposes. The Soxlet Extraction Method (502c) from Standard Methods[6] was the test procedure used for grease and oil determinations during this experiment.

Results & Discussion

The total and soluble COD concentrations of the poultry processing plant wastewater used as the feed source to the RBC units are shown in Table IX-2. The efficiency of the organic removal is primarily a function of the disc surface loading and retention time as well as a function of the treatability coefficient of the waste. At high organic concentrations (greater than BOD_5 150 mg/l), such as encountered with this waste, the principal design criterion is organic loading. Under these conditions, the rate that oxygen is supplied to the biofilm is not sufficient to metabolize the large amount of substrate diffusing into the film. A maximum removal rate is reached, beyond which the process exhibits zero order behavior. This phenomena is illustrated graphically in Figure IX-2.

The influent and effluent total COD concentrations, mass loading of COD to the units, mass of COD remaining in the effluent and the removal efficiency for the units are shown in Table IX-3. During the test the mass COD removal efficiency of RBC #1 averaged 92.5% with a range from 74.1% to 95.6% and RBC #2 averaged 94.0% with a range from 88.2% to 96.8%. The COD concentration of the feed applied to the units ranged from 1,140 mg/l to 4,700 mg/l. The effluent COD concentration from RBC #1 ranged from 60 mg/l to 295 mg/l and RBC #2 had concentrations from 50 mg/l to 230 mg/l. The effluent COD con-

Table IX-2

Total and Soluable COD
Concentration of RBC Feed

Days	Total COD mg/l	Soluable COD mg/l
1-2	1500	-
2-4	3400	435
4-5	4700	910
5-8	2300	1000
8-9	2200	960
9-11	1140	450
11-13	950	220
13-15	2240	-
15	1100	550
16	1900	-
16-19	1500	410
19-22	1200	400

FIGURE IX-2

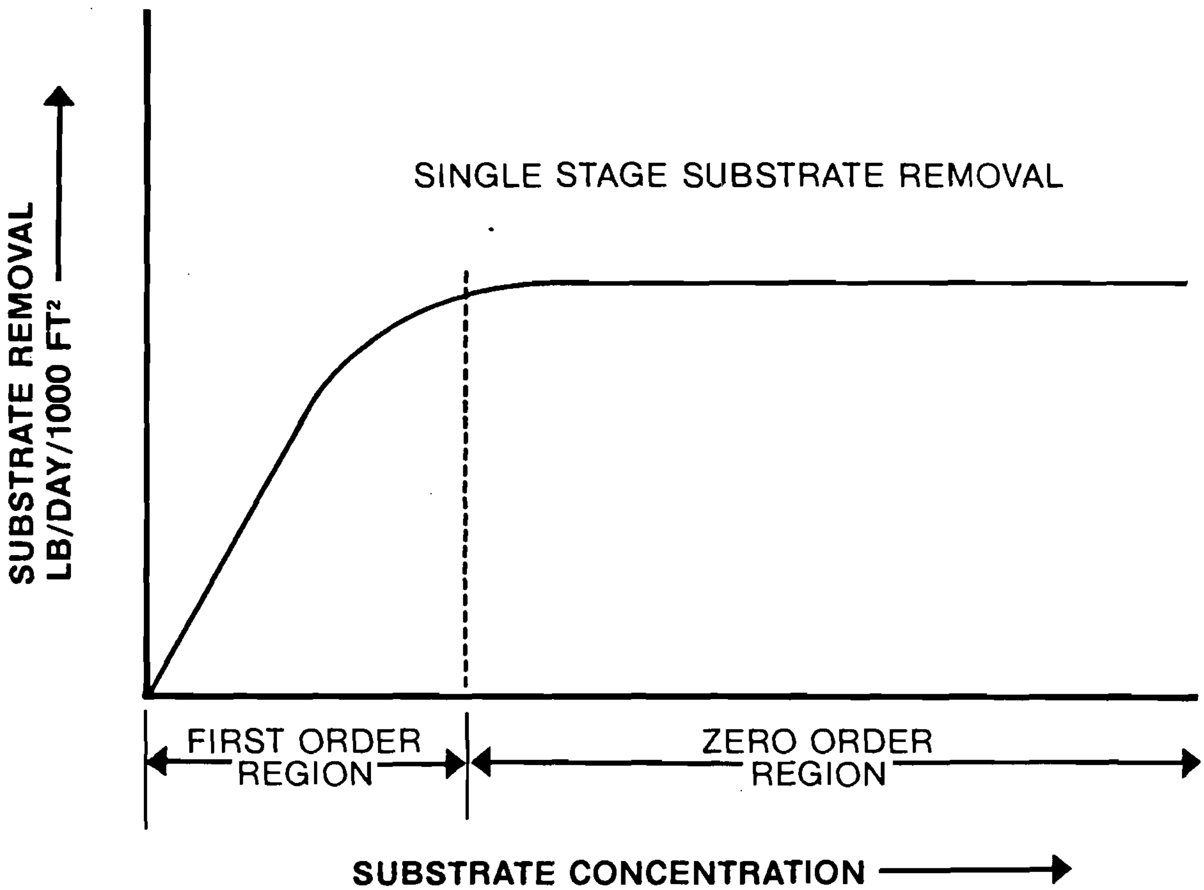

SINGLE STAGE SUBSTRATE REMOVAL
SUBSTRATE REMOVAL
LB/DAY/1000 FT²
FIRST ORDER
REGION
ZERO ORDER
REGION
SUBSTRATE CONCENTRATION

Table IX-3

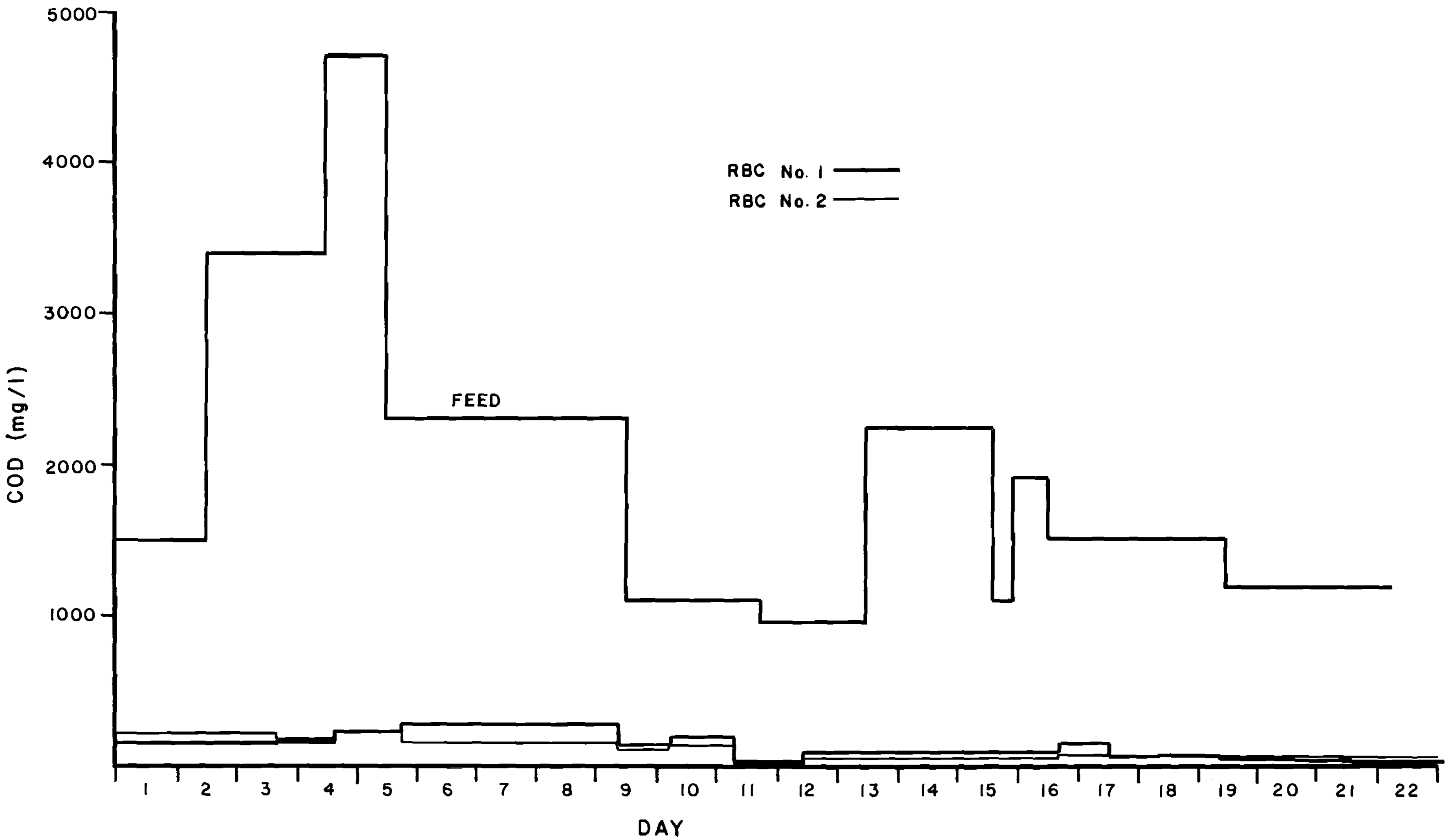
COD REMOVAL

Day	Time	Hours	Liters Applied	COD Feed mg/l	Effluent COD mg/l		COD grams Applied	Grams COD hour Applied	Grams COD in Effluent		% COD mass Removal	
					#1	#2			#1	#2	#1	#2
2	6:00 pm											
3	5:00 pm	23.0	11.8	3,400	150	230	40.1	1.74	1.77	2.71	95.6	93.2
4	3:00 pm	22.0	24	4,700	160	165	112.8	5.13	3.84	3.96	96.6	96.5
5	3:30 pm	24.5	16	2,300	220	220	36.8	1.50	3.52	3.52	90.4	90.4
6	12:45pm	21.2	14.7	2,300			33.8	1.59				
7	7:30 pm	30.7	20	2,300			46.0	1.50				
8	1:00 pm	17.5	12	2,200			26.4	1.51				
9	11:45am	22.7	16	1,140	295	175	18.2	0.802	4.72	2.80	74.1	84.6
10	8:30 am	20.7	20	1,140	155	135	22.8	1.10	3.10	2.70	86.4	88.2
11	8:30 am	24.0	21	1,000	200	150	21.0	0.875	4.20	3.15	80.0	85.0
12	9:00 am	24.5	25	950	65	50	23.7	0.970	1.55	1.25	93.5	94.7
13	8:00 am	23.0	23.5	2,240			52.6	2.29				
15	9:00 am	49.0	30	1,900			57.0	1.16				
16	2:00 pm	29.0	35.5	1,500	90	55	53.2	1.836	3.20	1.95	94.0	96.3
17	10:50am	21.2	31.8	1,500	170	50	47.7	2.25	5.41	1.59	88.7	96.8
18	8:00 am	20.8	21	1,500	80	75	31.5	1.514	1.68	1.58	94.7	95.0
19	1:00 pm	29.0	41	1,200	90	75	49.2	1.697	3.69	3.08	92.5	93.7
20	4:30 pm	27.5	25.5	1,200	70	70	30.6	1.113	1.78	1.78	94.2	94.2
22	1:45 pm	45.2	32	1,200	60	60	38.4	0.849	1.92	1.92	95.0	95.0
23	7:00 pm	29.2	20	1,200	7	70	24.0	0.821	1.40	1.40	94.2	94.2
					Total		547.2		41.78	33.39	92.5%	94.0%

centration generally increased with increased loading but high removal percentages were maintained at the higher loadings. The lower removal percentages at the decreased loading rates were most probably due to a lower mass transfer rate and a higher portion of refractory organics in the influent. The influent and effluent total COD concentrations are shown graphically in Figure IX-3. Daily organic (COD) and hydraulic loading applied to the units are shown in Table IX-4. The organic loading ranged from a low of 1081 mg COD/ft^2/day to a maximum of 6,917 mg COD/ft^2/day which represents a factor of 6.4 times between the minimum and the maximum. The hydraulic loading rate ranged from 0.877 liters/day/ft^2 to 2.022 liters/day/ft^2 (A 2.3 X change).

The effluent suspended solids concentrations are listed in Table IX-5. The highest concentration recorded by both units was 25 mg/l. RBC #1 had an average concentration of 12.7 mg/l and RBC #2 was slightly lower with an average of 9.2 mg/l. A sludge production rate was calculated by comparing the amount of COD consumed by the RBC's to the amount of suspended solids leaving the units. The sludge production rate for RBC 1 was 4.3 mg SS/mg COD destroyed and RBC #2 was 4.7 mg SS/mg COD destroyed.

The operating conditions of pH, dissolved oxygen (D.O) and temperature throughout the RBC units on various days during testing are shown in Table IX-6. The temperature of the wastewater was brought to approximately room temperature from its refrigerated temperature before entering the first stage of the RBC units. The units were operated at room temperature (19°C-23°C) and the



COD Concentrations of Influent and Effluent

FIGURE IX-3

Table IX-4

LOADING

Day	Organic Loading		Hydraulic Loading	
	mg COD/day/ft^2	lb/1000ft^2/day	liters/day/ft^2	gpd/ft^2
3	2346	5.17	0.692	0.183
4	6917	15.25	1.471	0.389
5	2025	4.46	0.881	0.233
6	2144	4.73	0.933	0.246
7	2022	4.46	0.877	0.232
8	2036	4.49	0.925	0.244
9	1081	2.38	0.948	0.250
10	1483	3.27	1.300	0.343
11	1180	2.60	1.180	0.312
12	1308	2.88	1.376	0.364
13	3088	6.81	1.378	0.364
15	1564	3.45	0.825	0.217
16	2475	5.46	1.651	0.436
17	3034	6.69	2.022	0.534
18	2014	4.44	1.361	0.360
19	2288	5.04	1.906	0.504
20	1501	3.31	1.250	0.330
22	1145	2.52	0.954	0.252
23	1107	2.44	0.922	0.244

Table IX-5

Effluent Suspended Solids Concentrations
in mg/l

Day	RBC#1	RBC#2
11	25	15
12	20	4
13	4	8
16	25	2
17	20	16
18	12	21
19	9	4
20	2	2
21	5	5
22	5	5
Average	12.7	9.2

Table IX-6
Operating Conditions

2 June 81

	DO(mg/l)	pH	Temp(°C)
1A	4.3	7.6	22
1B	4.1	7.6	22
1C	3.2	7.5	21
1D	5.4	7.7	21
2A	4.0	6.9	22
B	4.7	6.9	22
C	4.4	6.8	22
D	4.1	6.8	22
Feed	5.0	6.4	--

10 June 81

	DO(mg/l)	pH	Temp(°C)
1A	1.6	6.7	21
1B	3.3	6.8	21
1C	4.9	6.7	21
1D	5.1	6.7	21
2A	0.3	6.7	21
B	2.3	6.7	21
C	3.9	6.7	21
D	4.9	6.8	21
Feed	1.1	6.6	--

5 June 81

1A	0.60	7.1	22
B	0.40	7.2	22
C	0.40	7.2	22
D	0.30	7.2	22
2A	0.35	7.1	22
B	0.40	7.2	22
C	0.30	7.2	22
D	0.25	7.2	22

11 June 81

1A	0.3	6.5	22
B	3.3	6.5	22
C	3.7	6.5	22
D	3.2	6.4	22
2A	0.3	6.5	22
B	0.3	6.5	22
C	2.1	6.5	22
D	4.6	6.5	22

12 June 81

	DO(mg/l)	pH	Temp(°C)
1A	0.5	6.7	21
B	4.0	6.7	21
C	4.8	6.7	21
D	4.7	6.7	21
2A	0.8	6.7	21
B	3.5	6.8	21
C	5.2	6.7	21
D	6.4	6.6	21
Feed	0.7	6.2	--

17 June 81

	DO(mg/l)	pH	Temp(°C)
1A	6.3	6.3	22
B	6.6	6.3	22
C	6.3	6.3	22
D	6.7	6.2	22
2A	3.4	6.2	22
B	5.0	6.2	22
C	6.3	6.1	22
D	6.6	6.1	22

Table IX-6 (Continued)

	16 June 81			18 June 81		
1A	0.6	6.6	20	3.0	6.6	19
B	4.2	6.7	20	5.9	6.6	19
C	5.5	6.6	20	6.8	6.4	19
D	5.2	6.5	20	7.2	6.4	19
2A	0.5	6.8	20	3.0	6.2	19
B	2.9	6.9	20	4.2	6.3	19
C	4.3	6.6	20	6.1	6.3	19
D	6.0	6.4	20	6.8	6.1	19
Feed	6.4	6.6	--			

22 June 81

	DO	pH	Temp
1A	1.0	6.8	23
B	6.8	6.4	23
C	7.7	5.9	23
D	7.8	6.1	23
2A	0.9	6.9	23
B	6.1	6.5	23
C	6.6	6.2	23
D	6.9	6.2	23
Feed	3.0	6.4	--

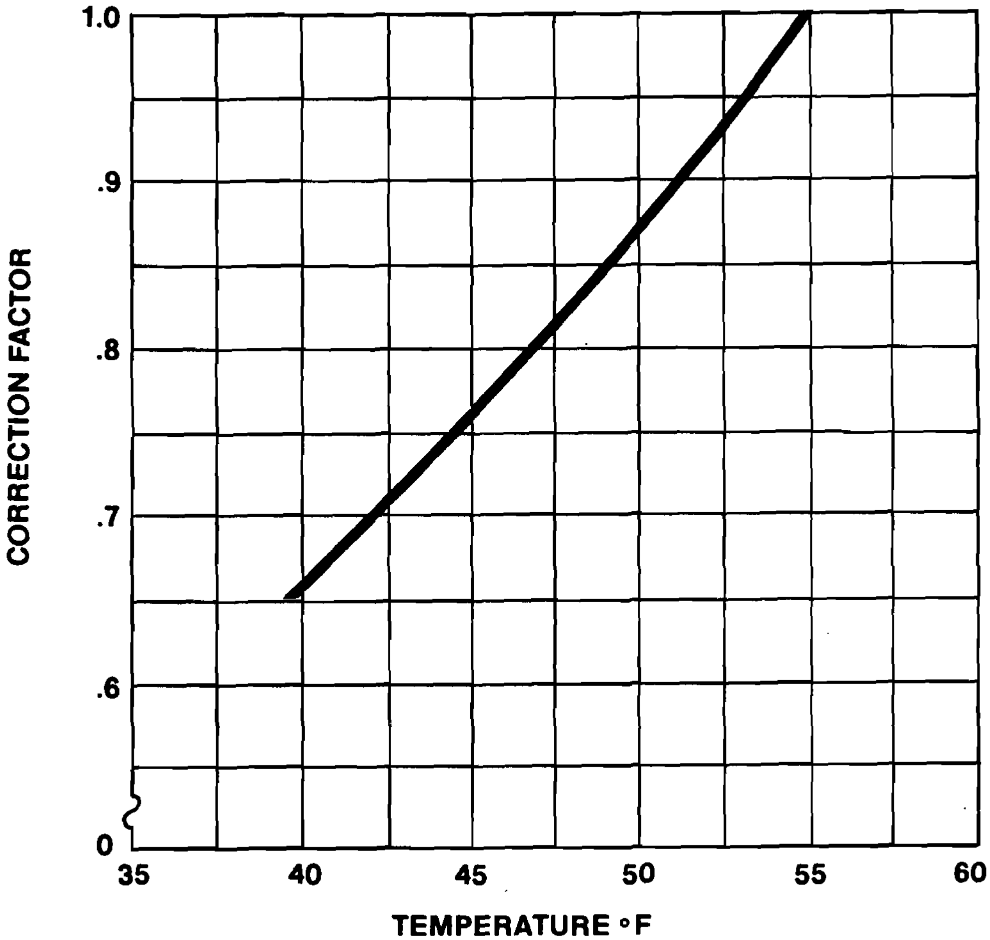
temperature throughout was quite uniform. If the temperature of the wastewater was to be less than 12.8°C (55°F) the temperature correction factors shown in Figure IX-4 would be used for design purposes because of the decline in treatment efficiency.

For the RBC process to be most effective, it is recommended that the pH be maintained between 6 to 9. Within this pH range, the treatment efficiency is maximized and growths of undesirable microbal species are discouraged. At low pH values, below 6.0, a predominance of yeasts and fungi occurs. At still lower pH values, less than 5.0, the predominately yeast and fungal culture can produce objectionable odors. Without any conditioning or buffering of the poultry processing wastewater used in this experiment, the pH inside the units essentially remained within the optimum range with pH values from 5.9 to 7.7.

Upon examining the Dissolved Oxygen (D.O.) values in Table IX-6 it can be seen that on several occasions the D.O. level in the first stages of the RBC units fell below 1.0 mg/l. Under these conditions where a low concentration of oxygen exists in the wastewater, the culture can become void of dissolved oxygen during the submerged portion of the rotation and a facultative culture may predominate. The organic removal rate of a facultative culture is less than that of a completely aerobic culture. Under low dissolved oxygen conditions the oxidation-reduction potential is lower which allows the development of undesirable microorganisms. These organisms oxidize sulfides rather than carbon, thus reducing treatment efficiency. The low D.O.

FIGURE IX-4

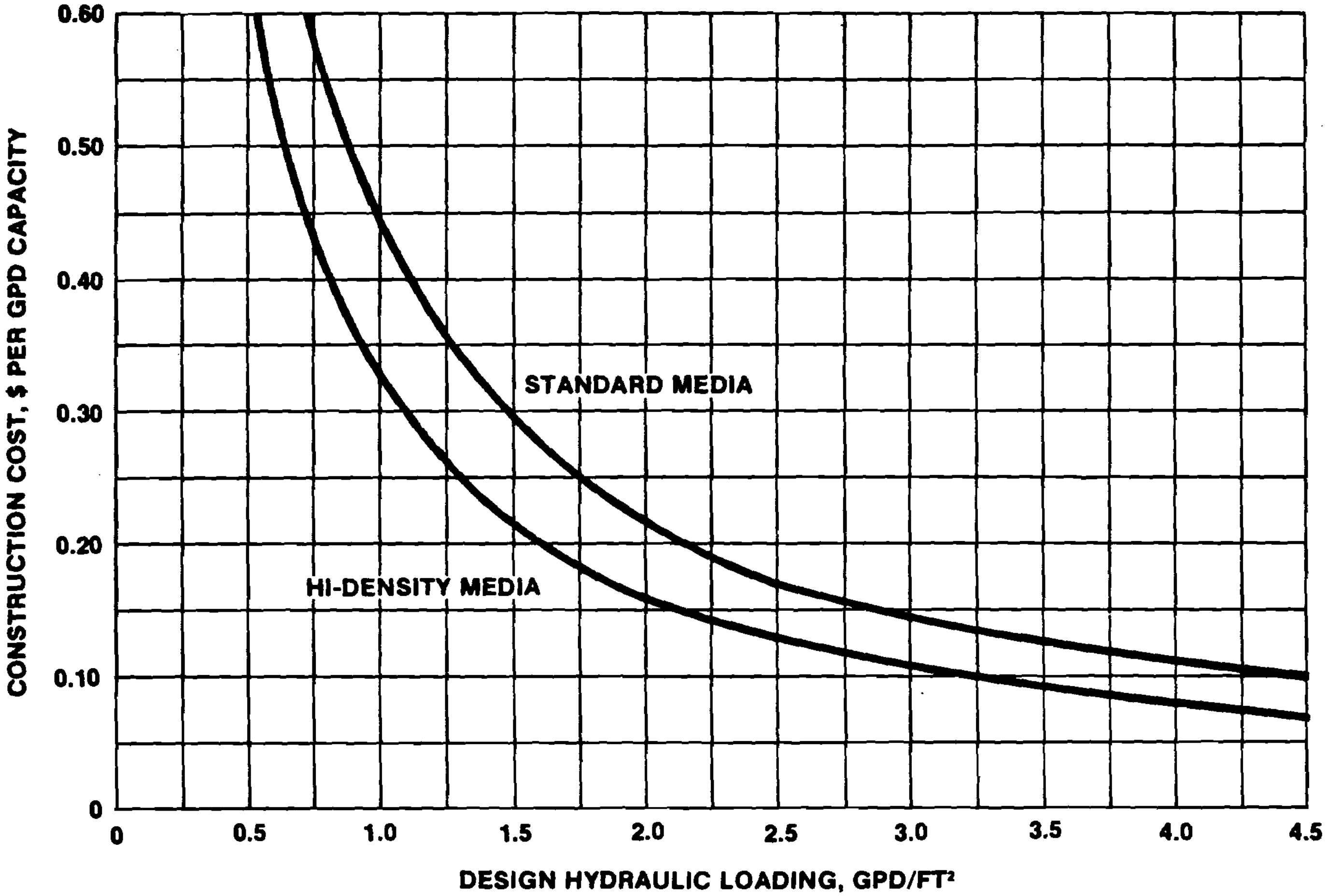
TEMPERATURE CORRECTION FOR BOD REMOVAL



in the first stages could have been the result of several factors. A low D.O. level in the feed wastewater could have been part of the problem. Probably the greatest contributor to the low D.O. was the high concentration of suspended solids that accumulated in the first stages. The reluctance of the suspended solids to pass through the units was due primarily to the low hydraulic loading and the design of the bench unit itself. The low hydraulic loading resulted in a high retention time and a slow linear flow rate through the units. The bench scale unit was constructed with flat plastic discs for ease in construction and to allow visual inspection of the microbal cultures. The flat discs did present certain problems: 1) they provided little agitation of the water while revolving; 2) they provided a low surface area to tank volume ratio (0.20 gal/ft^2) which increases the hydraulic retention time; and 3) the flat surface was susceptible to sloughing of large areas of biomass. The large pieces of sloughed biomass actually plugged the holes in the baffles on some occasions. This plugging should not be a problem on full scale units because during scale-up the drain holes would be greatly enlarged. Commercial RBC units have a honey-comb type media structure which should reduce many of the problems encountered with the flat discs.

Economics

In order to approximate the total construction costs for the RBC unit, the Autotrol Corporation prepared the table shown in Figure IX-5. The costs were determined by adding the costs of all process equipment and fiberglass enclosures, concrete tanks, freight for media



RBC CONSTRUCTION COSTS

FIGURE IX-5

assemblies and enclosures and installation costs. The total installed costs are expressed per unit of wastewater flow and shown separately as a function of hydraulic loading for both standard and Hi-density media. The costs shown do not include the expenses of treatment prior to the RBC, secondary clarification and sludge disposal. These costs vary significantly from one application to another, depending upon design flow, wastewater characteristics, degree of treatment, site conditions, and existing facilities.

For example, assume a plant processes 75,000 birds/day and produces a wastewater flow of 7 gallons/bird. The organic concentration of the wastewater entering the RBC is such that the necessary treatment is obtained at a hydraulic loading of 2.0 GPD/ft. Futher assume a media combination using 50% standard and 50% Hi-density. The standard media must be used in the first stage of treatment when the influent soluable BOD is greater than 90 mg/l.

Calculations

(75,000 birds/day) x (7 gallons/bird) = 525,000 gallons/day

From Figure IX-5

$ per gpd capacity
= 0.21 - .50 (0.21 - 0.16)
= 0.21 - 0.025
= 0.185

Construction costs
= 525,000 gpd x 0.185 $/gpd
= $97,125

Assume that this same plant, by incorporating an efficient water-usage management program, reduced its water consumption from 7 to 4 gallons/bird. If the program also resulted in a lower organic loading, so that the hydraulic loading applied to the RBC could be increased from 2.0 to 2.5 GPD/ft. Using the same treatment scheme as in the previous example the construction costs would be $45,000 as compared to $97,125 for the same plant before instituting a wastewater reduction program. In addition to reducing the construction costs by over 50%, savings would also result from lower water costs and reduced operational and maintenance expenses.

With increasing energy costs, energy consumption takes on a greater portion of the annual cost of operating a wastewater treatment facility. Therefore energy costs should be a predominant factor in the selection of cost-effective small-flow treatment systems. Energy consumption and estimated costs for the RBC and other biological treatment systems are compared in Table IX-7. When compared to these conventional treatment systems the RBC has a definite advantage. But where land is available at a reasonable cost, it is generally considered that land application wastewater treatment systems are the most energy-efficient systems. Low energy consuming wastewater treatment systems are generally easier to operate and maintain than energy-intensive systems, making the low energy consuming systems even more attractive because of the lower operation and maintenance costs and reduced need for highly skilled operators.

To estimate the economic viability of an RBC installation a hypothetical plant with the following typical conditions was analyzed:

Table IX-7

Energy Comparison of Biological Treatment Systems[7]

	Completely Mixed Activated Sludge	Extended-aeration Activated Sludge	Carousel-extended-aeration Activated Sludge	Pure-oxygen Activated Sludge	Bio-disk
kW demand	550	540	525	525	425
Cost, $	1 070	1 053	1 053	1 020	800
kWh usage	230 000	236 000	218 000	216 000	188 000
Cost, $	3 423	3 498	3 282	3 247	2 701
Monthly cost, $	4 498	4 542	4 335	4 076	3 501
Annual cost, $	53 976	54 504	52 020	48 804	42 012

Note - Comparison based on entire plant energy consumption in a hypothetical operation. Includes consideration of differences in sludge quantity and characteristics. Costs are based on varying rate schedules.

- o The wastewater from the plant is discharged into a municipal sewer system at a rate of 525,000 gallons/day;

- o The municipality has a surcharge of

- BOD over 250 mg/l	$ 50/1000 lbs.
- TSS over 250 mg/l	$ 50/1000 lbs.
- Oil & Grease over 100 mg/l	$200/1000 lbs.

- o The plant's current treatment system consists of primary and secondary screens followed by dissolved air flotation (DAF) without chemical addition and discharges the following effluent concentrations

  - BOD = 550 mg/l
  - TSS = 400 mg/l
  - Oil & Grease = 125 mg/l

The discharge concentrations listed above remain in excess of the maximum allowable concentrations permitted by the municipal treatment facility even though primary treatment techniques are utilized. This results in the following continuation of surcharges:

BOD	= $1,443/month	= $17,316/year
TSS	= $ 721/month	= $ 9,012/year
O&G	= $ 481/month	= $ 5,772/year
Total	= $2,645/month	= $31,740/year

The addition of the RBC system would reduce the concentration of the BOD, TSS and Oil and Grease to a level below their respective maximum allowable discharge limits thus eliminating all surcharges ($31,740/year).

The operating costs for the RBC would be as follows:

POWER CONSUMPTION

- 525,000 gallons/day
- 6 KW/MGD @ 2.5 GPD/ft^2

-6 KW/MGD x 0.525 MGD = 3.15 KW
-$0.05 KWH x 3.15 KW x 24 hr/day x 365 day/year = $1,380/year for electricity

OPERATION AND MAINTENANCE

-1 man-hour/shaft/week x 2 shafts x 52 week/year = 104 man-hour/year
-104 man-hours/year x $6.10/man-hour = $624/year for O&M

TOTAL OPERATING COSTS

$1,380/year for electricity
$ 624/year for O&M
$2,004/year for operation costs

Utilizing the above information, the RBC unit would have the following Simple Payback:

Net Savings = Surcharge saved - Operating Costs
$29,736/year = $31,740/year - $2,004/year

Payback Period = Capital Costs/Net Savings
3.28 years = $97,500/$29,736/year

For this hypothetical plant the addition of an RBC unit would be a very sound investment because of the relatively short back period resulting from the reduction in surcharge payments.

The values used to make these calculations are realistic numbers obtain from reviewing actual city surcharge rates, discharge data from operating poultry plants using DAF without chemicals, and RBC manufacturers design data.

Currently, the most popular pretreatment method fro the poultry industry that comes closest to eliminating surcharges is the use of DAF with chemical addition. There are several drawbacks to this system when compared to using the RBC system. First is the cost of the chemicals which reportedly can be up to several thousand dollars every month. Secondly the chemicals make the skimming very difficult to dewater during rendering. Some renders have actually refused to except these skimmings because of the added costs. Also for best performance a competent operators is needed on an almost full time basis.

Plants discharging wastewater directly into receiving bodies of water are required to have an NPDES permit. Plants must meet the discharge limitations stated in their permit or face fines or possibly closure of their operation. Discharge limitations imposed by NPDES permits required a substantially higher degree of treatment then do municipal pretreatment ordinances. The feasibility of a RBC system for direct discharges would result from an indepth comparison with other treatment systems. Because of the many variables that would be used in making such a comparison it could only practically be done on a case by case basis for individual plants.

REFERENCES

1. Hamm, D., "Characteristics of Effluents in Ten Southeastern Poultry Processing Plants," Poultry Science, 51:825-829 (1972).

2. Autrotrol Corp., "Autotrol Wastewater Treatment Systems, Design Manual," (1979).

3. Ibid.

4. "Standard Methods for the Examination of Water and Wastewater," 14th Ed., Amer. Public Health Assn., Washington, D.C. (1975).

5. Ibid.

6. Ibid.

7. "Energy Conservation in Municipal Wastewater Treatment", U.S. Environmental Protection Agency, EPA 43019-77-011, MCD-32, Washington, D.C., 1977.

SECTION X

POULTRY PROCESSING PLANT NOISE ABATEMENT DEMONSTRATION

by J. Craig Wyvill

Introduction

The activities described in this section are part of nearly three years of research to develop workable methods of quieting poultry processing plants. In our July 1980 final report,[1] we made note that our development activities were continuing under a matching grant from the National Aeronautics and Space Administration. These activities were concluded in April of 1981 and a comprehensive final report written. The results of this research provide the tools that are to be used in the noise abatement demonstration effort.

Due to the delay in completing this critical research we have not yet implemented the full scale demonstration of noise control techniques at a processing plant. We have, however, held a small scale laboratory demonstration on the Georgia Tech campus and are currently scheduling the full scale demonstration for the fall of 1981 at Tip Top Poultry in Marietta.

This report summarizes the activities which have taken place both in regard to the small scale demonstration and in finalizing arrangements for the full scale plant demonstration. Because of the significance of our recent research findings, they are also summarized to highlight those measures which will be utilized in the demonstration.

Laboratory Demonstration

On October 29, 1980 a small scale laboratory demonstration of the effectiveness of fiberglass panels in abating poultry processing plant noise was held on the Georgia Tech campus. Table X-1 presents a list of attendees present at that demonstration.

The program entailed utilizing a small reverberant chamber (20 x 24') located on the Georgia Tech campus. The chamber was first filled with broadband noise such that the reverberant sound field had an average intensity of 92 dBA. Next actual recordings made in a poultry processing plant environment were played in the chamber again at an average reverberant sound field intensity of 92 dBA. This second measure was taken to simulate actual processing conditions. The chamber was then outfitted with 28 fiberglass panels which were hung in parallel rows from the ceiling at 2 foot intervals (see Figure X-1). The panels were encased in a 1 mil thick polyester film pouch to simulate the type of sanitary covering required for placement of such panels in a processing plant. The experiment was then repeated with the sound power input to the chamber consistant with that used in the earlier test. The result was a significant drop in sound pressure level (on average approximately 7 dBA) throughout the chamber signifying the abatement of reflected sound.

The noise demonstration also afforded the study team an opportunity to evaluate the accuracy of calculating techniques used in predicting sound pressure level drops caused by the change in room absorption characteristics brought about by the addition of panels to the ceiling of the room.

Table X-1

List of Attendees
Poultry Processing Noise Abatement Demonstration
October 29, 1980

Name	Org/Location
Sandy Tingley	NASA/Cleveland
Dr. John Cobb	Georgia Department of Agriculture/Atlanta
Craig Wyvill	Georgia Tech EES/Atlanta
Richard Combes	Georgia Tech EES/Atlanta
Wm. Morrison	Georgia Tech ATDC/Atlanta
Tom Towers	OSHA/Washington
Ray Kunicki	OSHA/Washington
Bob Turley	ConAgra Poultry/Dalton, Georgia
Lamar Fair	ConAgra Poultry/Dalton, Georgia
Walt Puryear	GoldKist Poultry/Athens, Georgia
Hubert Bunch	GoldKist Poultry/Ellijay, Georgia
Bob Bremmer	GoldKist Poultry/Carrolton, Georgia
Geo. Deadwyler	Wayne Poultry/Pendergrass, Georgia
Elton Maddox	Wayne Poultry/Pendergrass, Georgia
Tom Kirchoff	Central Soya Poultry/Athens, Georgia
Abit Massey	Georgia Poultry Federation/Gainesville, Georgia
*Jim Burruss, Jr.	Tip Top Poultry/Marietta, Georgia
*Chet Austin	Tip Top Poultry/Marietta, Georgia
*Buddy Burruss	Tip Top Poultry/Marietta, Georgia

* - attended a separate demonstration on October 27

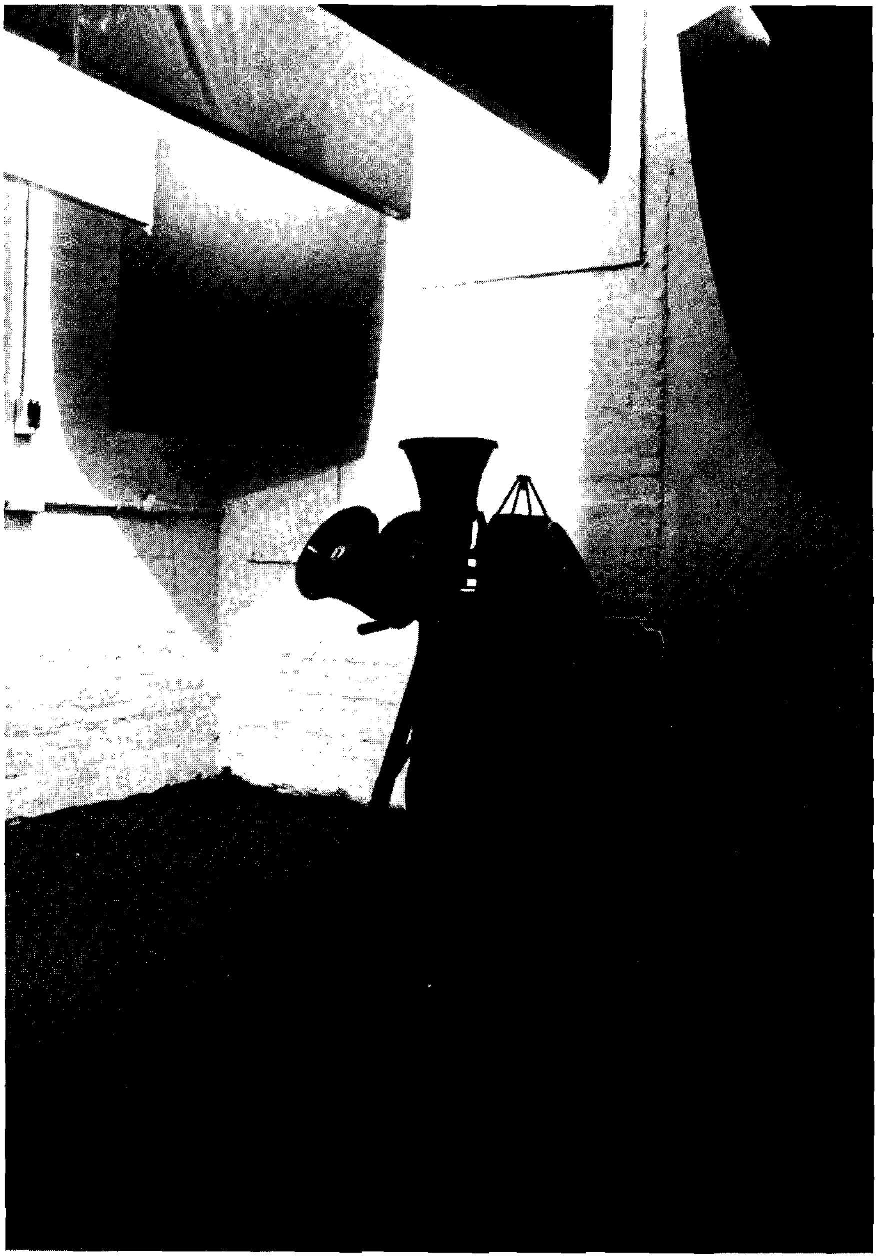


FIGURE X-1 PANEL ARRANGEMENT IN REVERBERANT ROOM

The procedure involved measuring the average drop in sound pressure level in the reverberant sound field of the chamber after the panels used in the demonstration were added. For this test an accurate, steady state, broadband noise source was required. To meet this need, a B&K model 4205 noise generator was used in conjunction with an amplifier, digital voltmeter (for control purposes) and a multiple loudspeaker system positioned in the corner of the chamber.

The sound pressure level was recorded utilizing a free field condenser microphone whose signal was recorded for subsequent frequency analysis. Figure X-2 displays the equipment arrangement for the test. The measured sound pressure level reductions are shown in Table X-2.

The calculation procedure involved utilizing the absorption characteristics of the room and the absorptive panels as presented in Table X-3 in the following equation[2]:

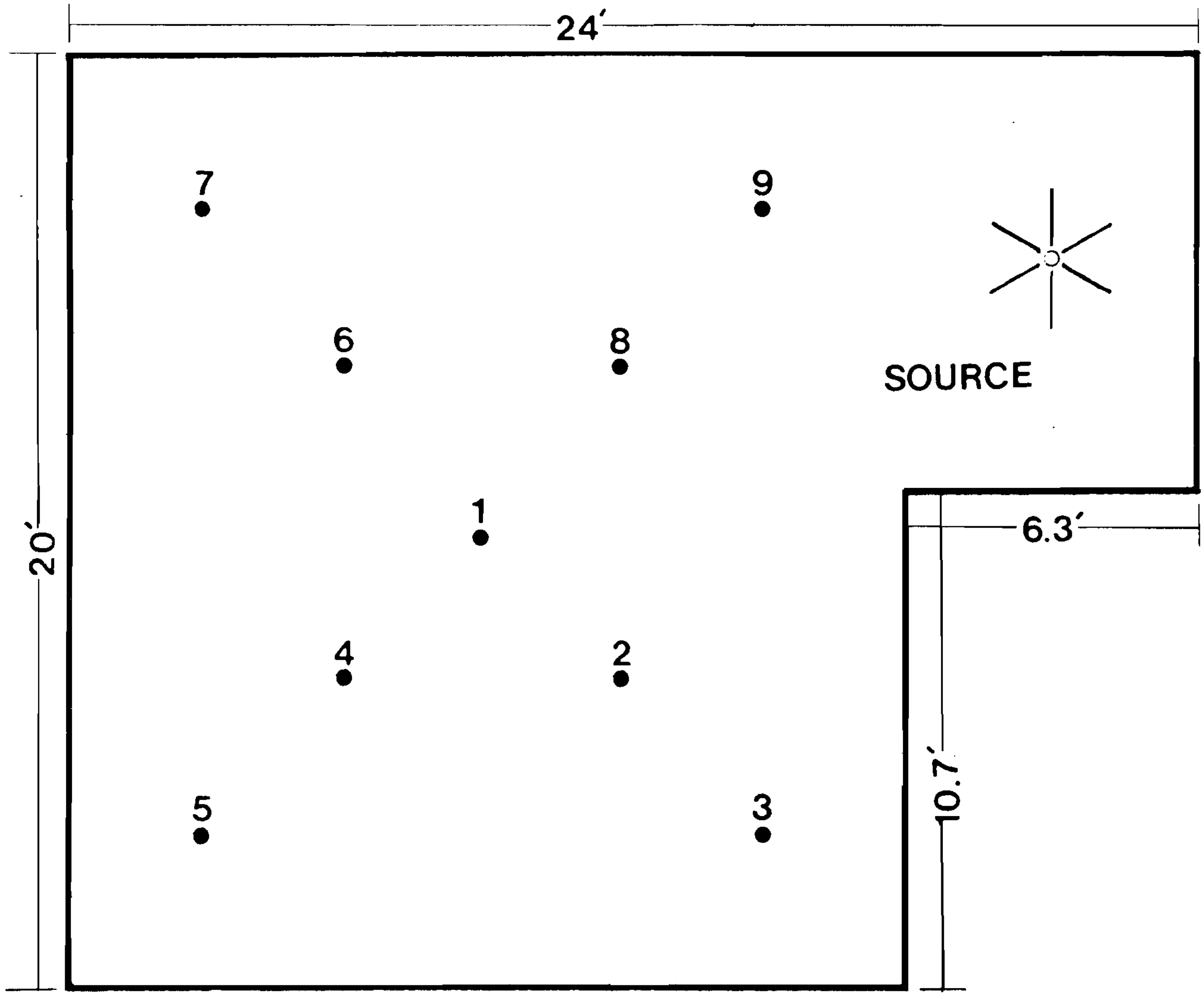
$$\Delta Lp = 10 \log \frac{\alpha_R S_R}{\alpha_R S_R + \alpha_P S_P} \qquad \text{(EQ 1)}$$

where

ΔLp = estimated reduction in sound pressure level
α_R = average surface absorption characteristics of the chamber
S_R = surface area of the chamber not covered with panels
α_P = average absorption characteristics of the panels
S_P = surface area of the chamber covered with panels

Table X-4 presents the values of S_R and S_P utilized in the calculation. Table X-5 presents the sound pressure level reductions calculated.

Utilizing an arithematic average of the four octaves studied, the average overall calculated sound pressure level reduction was 6.5 dB



MICROPHONE HEIGHT - 3.4 ft

ROOM HEIGHT - 8.8 ft

FIGURE X-2

MEASUREMENT POINTS IN REVERBERANT ROOM

Table X-2

Measured Sound Pressure Level
Reductions with Panels Added

Octave	Sound Pressure Level Reduction
500 Hz	6.50 dB
1000 Hz	7.60 dB
2000 Hz	6.40 dB
4000 Hz	6.56 dB

Table X-3

Absorption Characteristics of Test
Panels* and Reverberant Room

Octave	Absorption Coefficient	
	Panel	Room
500 Hz	0.805	0.0485
1000 Hz	0.824	0.0519
2000 Hz	0.744	0.562
4000 Hz	0.543	0.614

*panels were constructed of Series 703 Semirigid Owens/Corning fiberglas encased in 1 mil duPont mylar®

Source: J. C. Wyvill and W. G. Morrison, A Study of Poultry Processing Plant Noise Control Techniques (Atlanta: Georgia Institute of Technology Engineering Experiment Station, 1981) p. 34, B-2.

Table X-4

Surface Area Values Corresponding to
Covered and Uncovered Regions of the Test Chamber

Surface Area uncovered (S_R)	= 1600 ft^2
Surface Area covered (S_p)	= 412 ft^2

Table X-5

Calculated Sound Pressure Level
Reductions with Panels Added

Octave	Sound Pressure Level Reduction
500 Hz	7.22 dB
1000 Hz	7.05 dB
2000 Hz	6.44 dB
4000 Hz	5.16 dB

and the average overall measured reduction was 6.7 dB. This finding in conjunction with the nearness of the individual values in each octave reinforced our confidence in these calculations techniques.

Full Scale Plant Demonstration

Efforts to organize a full scale plant demonstration focused on three issues:

- o secure the commitment of a plant to allow the demonstration to take place.
- o secure the support of national poultry groups and the interest of processors around the country in the demonstration.
- o secure additional financial support to augment those being provided by the Georgia Department of Agriculture.

Due to the close working relationship established with Tip Top Poultry, they were the first plant approached regarding the demonstration. Their close proximity to Atlanta made them ideal in terms of accessibility to both processors and interested parties in the state and processors and interested parties throughout the country. They were also asked to contribute nominal funding toward the project to help defray the cost of material acquisitions. Their response was a firm yes.

At least two other plants were approached regarding the demonstration. In both cases, the plants were unable to provide the nominal funding requested to help defray the cost of material acquisitions.

The support of the National Broiler Council was secured in October of 1980 (see Figure X-3). In January of 1981 over 270 poultry processors around the country were notified of our progress in abating processing plant noise. Over 90 of these processors responded by seeking further information on how to abate noise.

In October and November of 1980 a series of discussions transpired with representatives of the Directorate of Science and Technology of the Occupational Safety and Health Administration. Their response toward supporting the demonstration and publicizing our study findings was very favorable. In October of 1980, a proposal was submitted to them requesting matching funds in the amount of $70,000 for use on the program. Unfortunately, a reorganization subsequently took place in the sponsors office and programmatic changes resulted in their inability to help fund the project.

In order to react to this setback, we immediately sought the support of Owens/Corning Fiberglas and Howe and Bainbridge, Inc. to provide support to our program. These two companies manufacture materials that will be used to fabricate panels for the demonstration.

Owens/Corning responded by offering to provide free fiberglass materials to the program. In addition they contacted one of their fabricators who subsequently agreed to construct the panels free of charge.

Howe and Bainbridge agreed to provide the panel covering material at 1/3 the normal wholesale price.

National Broiler Council

October 20, 1980

Mr. J. Craig Wyvill, P. E.
Research Engineer
Technology Applications Laboratory
O'Keefe Room 221
Engineering Experiment Station
Atlanta, GA 30332

Dear Craig:

Tha National Broiler Council which represents producer/processors of over 75% of the broilers (young meat chickens) marketed in the United States is continually and vitally concerned with noise abatement in broiler processing plants. We strongly support your efforts and research to reduce the noise level for processing plant employees.

To conduct a full-scale noise abatement demonstration in actual processing plants is a very logical and essential step toward achieving an acceptable level of noise abatement. Further, if you can solve the very serious problems confronting poultry processors regarding noise abatement, the results should have very direct and useful application in a wider range of plants outside the poultry industry.

Let us know how we can assist you in gaining OSHA support for this much needed project.

Sincerely,

William P. Roenigk
Director of Economic Research

WPR/baa

The Madison Building-Suite 614/1155 Fifteenth Street, N.W./Washington, D. C. 20005/202 296-2622

FIGURE X-3

Currently the demonstration is slated for the fall of 1981. A workshop is also planned to discuss the research fundings with processors from across the state.

Summary of Research Findings Relative to Noise Control[3]

Based on the recently completed research focused on effective methods of dealing with poultry processing noise it was concluded that a number of techniques do exist. While the exact approach to solving noise problem necessitates some understanding of the specific plant environment to be treated, in general covering the ceiling of a plant with a noise-absorbing medium is a practical first step. Once the reflected noise levels have been abated, then treatment of specific, identifiable noise sources can better take place. The logic behind this recommendation results from our earlier findings that much of the noise observed in a typical plant is caused by the poor acoustic qualities of the plant rather than the presence of numerous, loud noise sources.

In selecting a ceiling treatment, attention must be given to maintenance and replacement costs in addition to purchase and installation costs. Our research revealed a host of potential maintenance problems with noise panels if inadequate attention is given to the demands which will be placed on the covering medium during normal plant operations. Because the cover must remain intact to comply with USDA cleanability requirements, we recommend the use of rugged fiber-reinforced plastic covers to minimize the potential for failure. This results in a potentially higher panel cost but yields one which will last many years. We stress this because the cover is only a portion of the total cost which goes into panel construction, yet its failure renders the entire panel useless.

The fiber-reinforcement also allows the cover thickness to be kept at a minimum while achieving the desired strength characteristics. A series of tests revealed that as cover film thickness is increased, panel absorption above 800 Hz is reduced at an accelerated rate toward higher and higher frequencies. Below 800 Hz, absorption is increased with thicker films (see Figure X-4). The fiber-reinforced material has the acoustic properties of a 1 mil film and the strength characteristics of a 2 to 3 mil film.

With regard to mounting panels in a plant we found that noise panels suspended vertically from the ceiling were best. Our research showed a spacing of 3 feet between panels as a satisfactory spacing. However closer spacings could be chosen if the plant is attempting to bring about a larger amount of noise reduction or trying to improve low-frequency absorption. By our calculations, the 3-foot spacings should provide a 5 to 6 dB reduction in reverberant noise level at the plants presented in our previous report.

With regard to source quieting, a key word must be maintenance. Improperly maintained machinery was one of the leading causes noted for high machinery noise levels. We found that poorly maintained machinery can be located using a portable vibration meter. This provides a means of initiating preventive maintenance which can lower machinery noise levels.

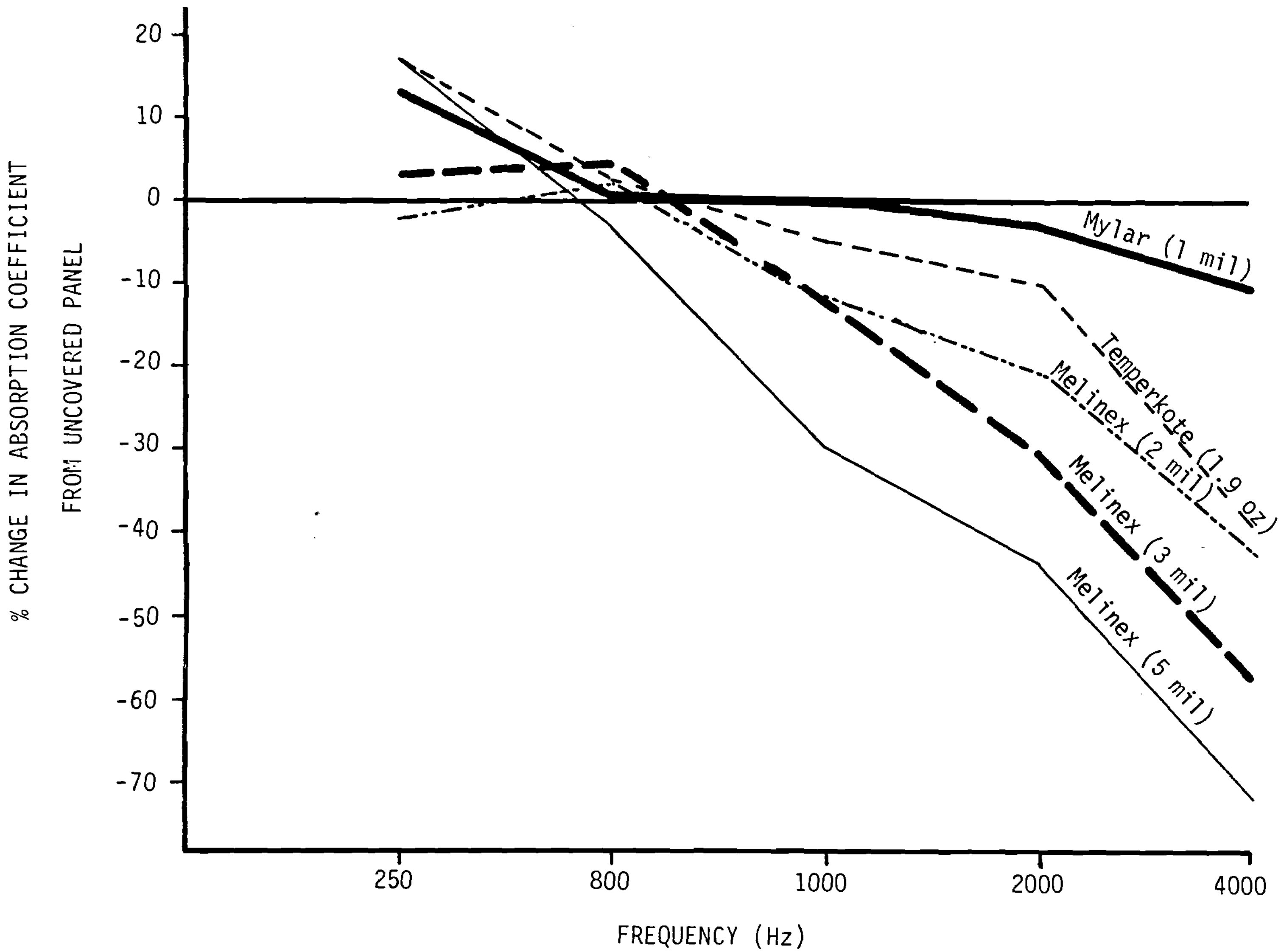


FIGURE X-4- Percentage Change in Absorption Coefficient for
Panel after Plastic Cover is Added

In addition, it was found that isolating drive motors and pumps from large expansive surface areas, such as those on a chiller was important to controlling machinery noise. Such measures as flexible connecting tubes between pumps and chiller bodies could mean a substantial reduction in local sound pressure levels near the chiller. Drive motors could also be placed under hoods filled with absorbing medium to reduce their sound power emission to the plant and pneumatic exhausts could easily be muffled. A large number of companies design inexpensive mufflers for just such an application.

Lung guns, on the other hand, remain a problem where they must still operate. The most logical solution is to contain lung gun noise through the use of partial plastic barriers between individual operator stations. However, this demands that an absorbing medium be placed over the station to prevent sound pressure buildup to the operator. Furthermore, the barriers must not be high enough to isolate the head of the operator from others in the plant.

Lastly, ice chutes, it was found, could be insulated for both energy conservation and abatement of noise related to ice transport and discharge. There are a number of good vibration dampening mediums that are efficient thermal insulators as well.

Conclusion

While the full scale plant demonstration of noise abatement techniques has not taken place, considerable progress has been made toward that goal. Research findings suggest that considerable noise reduction is achievable with the techniques developed and that the techniques are durable enough to withstand the harsh processing environment. A plant has been secured for the demonstration and considerable interest and support found for seeing its implementation. Industrial firms have taken an interest in making some of the new techniques commercially available and have agreed to contribute time and materials to the demonstration. In summary, the scheduled demonstration should provide an effective forum for exhibiting the results of three years of research to find workable solutions to the poultry processing noise problem.

REFERENCES

1. Atkins, Dale, et al, Georgia Poultry Industry Research, Final Report for Project A-2464, Georgia Institute of Technology Engineering Experiment Station, TAL, Atlanta, Ga., August 1980, pp. 78-95.

2. Beranek, Leo L., Noise and Vibration Control, McGraw-Hill Book Company, 1971.

3. Wyvill, J. C. and Morrison, W.G., Jr., A Study of Poultry Processing Plant Noise Control Techniques, Final Report for NASA Research Grant No. NSG3228, Georgia Institute of Technology Engineering Experiment Station, 1981.

APPENDIX A
ENERGY CONSUMPTION SURVEY AND
POULTRY ENGINEERING PROGRESS NEWSLETTER

Energy Consumption Survey

Each year since 1976 the Georgia Tech Engineering Experiment Station has conducted an energy consumption survey for the State's poultry industry. This survey is intended to give its participants an opportunity to compare the energy usage characteristics of their particular plant to those of other poultry plants producing the same product. The survey encompasses four different poultry operations; broiler processors, egg processors, hatcheries, and feed mills.

Requests for energy consumption data for 1980 were mailed to 36 plants. The information asked for included usage and cost of electricity, natural gas, propane, and fuel oil as well as annual production. Utilizing the data provided by the plants themselves, the annual energy usage and yearly energy cost for each survey respondee were computed. Then total plant energy usage per unit of production and the dollar cost of energy per unit of production were determined so that the plants could be compared on the basis of their effective use of energy.

Once the BTU usage for an entire industry segment is totaled up, the average number of BTU per unit of production for each of the plant types is developed. Along with the average industry cost of energy per unit of production, this ratio forms a basis on which the effectiveness of industry energy conservation efforts can be measured. The results obtained in the current survey are then compared to the results of previous years and an estimate of the percent increase or decrease in energy consumption calculated.

Energy information on Georgia's broiler processing industry is listed in Tables A-1 and A-2. Tables A-3 and A-4 give the same information for the State's egg processors. The data for hatching operations may be found in Table A-5 and Table A-6, followed by the survey results for Georgia feed mills in Tables A-7 and A-8.

In the above tables, the year 1978 was used as the reference year. For the years 1976 and 1977, some plants answered the survey that did not answer in 1978. The replies of these plants are not tabulated in Tables A-1 through A-8. Only those plants who also responded in 1978 are shown. However, in summary Tables A-9 through A-12 all the data received from all the survey respondees has been reduced to obtain the averages and ranges reported therein. These summary tables recap the yearly survey results for all participants since the survey's inception in 1976.

The results of the 1980 poultry energy consumption survey show that the State's broiler processors are successfully reducing their usage and cost of energy per production unit. Other segments of Gerogia's poultry industry do not fare as well, although feed mills experienced a significant decline in energy usage and cost during the current year. Egg processors are currently exhibiting an upward trend, but the size of the industry sample is somewhat small for this to be definitive. One can sense the rising cost of energy from the fact that only seven of the twenty-five survey respondees experienced a decline in their average energy cost per unit of production and these seven were confined to two of the industry groups.

Clearly, the potential for energy conservation still exists in many industry segments. As a source of energy expertise and information, Georgia Tech will continue to conduct the poultry industry energy survey as an information service to Georgia's industrial poultry community.

Table A-1

Energy Survey Results
Georgia Broiler Processors

Code Number	Ratio	1976	1977	1978	1979	1980
10001	BTU/1000 lbs.	1,708,841	836,154	722,642	519,642	515,281
	$/1000 lbs.	4.37	3.97	4.84	2.67	3.06
10002	BTU/1000 lbs.		830,852	835,689		565,862
	$/1000 lbs.		2.88	3.85		3.16
10003	BTU/1000 lbs.	867,856	806,073	755,034	689,510	504,742
	$/1000 lbs.	3.57	3.67	3.76	3.91	3.29
10004	BTU/1000 lbs.	1,284,920	698,725	707,297	549,322	475,559
	$/1000 lbs.	4.74	3.13	2.47	2.23	2.44
10005	BTU/1000 lbs.					
	$/1000 lbs.					
10006	BTU/1000 lbs.					
	$/1000 lbs.					
10007	BTU/1000 lbs.	1,126,037	906,490	839,071	781,692	623,360
	$/1000 lbs.	4.42	3.54	3.62	3.77	4.06
10008	BTU/1000 lbs.					
	$/1000 lbs.					
10009	BTU/1000 lbs.					
	$/1000 lbs.					
10010	BTU/1000 lbs.					533,329
	$/1000 lbs.					3.29
10011	BTU/1000 lbs.	783,254		816,867	584,070	489,172
	$/1000 lbs.	3.51		3.83	3.13	3.11
10012	BTU/1000 lbs.			709,476		655,301
	$/1000 lbs.			3.25		3.77
10013	BTU/1000 lbs.	1,312,161		1,028,117	1,121,165	
	$/1000 lbs.	5.75		5.19	5.86	
10014	BTU/1000 lbs.	1,278,445		1,085,032	946,558	
	$/1000 lbs.	4.15		4.36	4.19	
10015	BTU/1000 lbs.			878,100		
	$/1000 lbs.			4.48		
10016	BTU/1000 lbs.				1,562,265	
	$/1000 lbs.				6.74	
10017	BTU/1000 lbs.					
	$/1000 lbs.					
Average	BTU/1000 lbs.	1,407,211	952,864	834,639	810,637	553,183
	$/1000 lbs.	4.66	3.97	3.87	3.88	3.27

Table A-2

Percent Change Over Previous Year
Georgia Broiler Processors

Code Number	Ratio	1977	1978	1979	1980
10001	BTU/1000 lbs.	-51.07	-13.65	-28.00	-0.84
	$/1000 lbs.	-9.15	+10.62	-44.83	+14.6
10002	BTU/1000 lbs.		+0.58		-32.29a
	$/1000 lbs.		+33.45		-17.92a
10003	BTU/1000 lbs.	-7.12	-3.85	-8.69	-26.80
	$/1000 lbs.	+2.80	+2.37	+3.96	-15.86
10004	BTU/1000 lbs.	-45.62	+1.27	-22.34	-13.43
	$/1000 lbs.	-33.97	-21.07	-9.72	+9.42
10005	BTU/1000 lbs.				
	$/1000 lbs.				
10006	BTU/1000 lbs.				
	$/1000 lbs.				
10007	BTU/1000 lbs.	-19.50	-7.44	-6.84	-20.26
	$/1000 lbs.	-19.91	+2.24	+4.20	+7.69
10008	BTU/1000 lbs.				
	$/1000 lbs.				
10009	BTU/1000 lbs.				
	$/1000 lbs.				
10010	BTU/1000 lbs.				
	$/1000 lbs.				
10011	BTU/1000 lbs.		+4.29a	-28.50	-16.25
	$/1000 lbs.		+9.12a	-18.21	-0.64
10012	BTU/1000 lbs.				-7.64a
	$/1000 lbs.				+16.00a
10013	BTU/1000 lbs.		-21.65a	+9.05	
	$/1000 lbs.		-9.74a	+12.91	
10014	BTU/1000 lbs.		-15.13a	-12.76	
	$/1000 lbs.		+5.06a	-3.90	
10015	BTU/1000 lbs.				
	$/1000 lbs.				
10016	BTU/1000 lbs.				
	$/1000 lbs.				
10017	BTU/1000 lbs.				
	$/1000 lbs.				
Average	BTU/1000 lbs.	-32.29	-12.4	-2.88	-31.76
	$/1000 lbs.	-14.81	-2.52	+0.26	-15.72

a) Current figure compared to results from 2 years ago. Plant did not respond to survey during previous year.

Table A-3

Energy Survey Results
Georgia Egg Processors

Code #	Ratio	1976	1977	1978	1979	1980
20001	BTU/1000 doz eggs			458,860		620,890
	$/1000 doz eggs			4.77		5.38
20002	BTU/1000 doz eggs	237,924	248,340	266,939		
	$/1000 doz eggs	1.64	2.00	2.33		
20003*	BTU/1000 doz eggs	71,285	75,104	111,443		
	$/1000 doz eggs	0.86	0.96	1.54		
20004	BTU/1000 doz eggs	672,652	401,019	459,005		
	$/1000 doz eggs	4.14	3.68	4.06		
20005	BTU/1000 doz eggs	317,888	267,746	277,766		234,813
	$/1000 doz eggs	1.12	1.13	1.34		1.46
Average	BTU/1000 doz eggs	370,567	278,022	359,639		410,149
	$/1000 doz eggs	2.09	2.01	2.99		3.24

Table A-4

Percent Change Over Previous Year
Georgia Egg Processors

Code #	Ratio	1977	1978	1979	1980a
20001	BTU/1000 doz eggs				+35.31
	$/1000 doz eggs				+12.79
20002	BTU/1000 doz eggs	+4.38	+7.49		
	$/1000 doz eggs	+22.30	+16.28		
20003*	BTU/1000 doz eggs	+5.36	+48.38		
	$/1000 doz eggs	+11.61	+60.15		
20004	BTU/1000 doz eggs	-40.38	+14.46		
	$/1000 doz eggs	-11.13	+10.19		
20005	BTU/1000 doz eggs	-15.77	+3.74		-15.46
	$/1000 doz eggs	+1.17	+18.71		+8.96
Average	BTU/1000 doz eggs	-24.97	+29.36		+14.04
	$/1000 doz eggs	-3.64	+48.41		+8.36

a) All current results compared to 1978 figures. No plants responded in 1979

* Electricity Only

Table A-5

Energy Survey Results
Georgia Hatcheries

Code Number	Ratio	1976	1977	1978	1979	1980
30001	BTU/1000 birds	338,876	281,835	319,076		354,896
	$/1000 birds	1.81	1.87	2.01		2.46
30002	BTU/1000 birds		246,979	202,161		225,785
	$/1000 birds		1.24	1.11		1.60
30003	BTU/1000 birds		198,803	257,736		
	$/1000 birds		1.35	1.70		
30004	BTU/1000 birds			488,921		606,445
	$/1000 birds			2.10		3.46
30005	BTU/1000 birds			408,311		
	$/1000 birds			2.47		
30006	BTU/1000 birds			373,527		325,526
	$/1000 birds			3.41		3.89
30007	BTU/1000 birds			385,581		460,587
	$/1000 birds			2.52		3.53
30008	BTU/1000 birds			236,662		
	$/1000 birds			3.76		
30009	BTU/1000 birds				320,832	213,428
	$/1000 birds				1.89	2.45
30010	BTU/1000 birds					290,677
	$/1000 birds					1.96
30011	BTU/1000 birds					347,683
	$/1000 birds					2.44
30012	BTU/1000 birds					332,553
	$/1000 birds					3.50
Average	BTU/1000 birds	338,876	235,985	351,845	320,832	377,368
	$/1000 birds	1.81	1.49	2.14	1.89	2.81

Table A-6

Percent Change Over Previous Year
Georgia Hatcheries

Code Number	Ratio	1977	1978	1979	1980a
30001	BTU/1000 birds	-16.83	+13.21		+11.23
	$/1000 birds	+3.31	+7.66		+22.39
30002	BTU/1000 birds		-18.15		+11.69
	$/1000 birds		-10.54		+44.14
30003	BTU/1000 birds		+29.64		
	$/1000 birds		+25.93		
30004	BTU/1000 birds				+24.04
	$/1000 birds				+64.76
30005	BTU/1000 birds				
	$/1000 birds				
30006	BTU/1000 birds				-12.85
	$/1000 birds				+14.08
30007	BTU/1000 birds				+19.45
	$/1000 birds				+40.08
30008	BTU/1000 birds				
	$/1000 birds				
30009	BTU/1000 birds				-33.48
	$/1000 birds				+29.63
30010	BTU/1000 birds				
	$/1000 birds				
30011	BTU/1000 birds				
	$/1000 birds				
30012	BTU/1000 birds				
	$/1000 birds				
Average	BTU/1000 birds	-30.36	+49.10	-8.81	+17.62
	$/1000 birds	-17.68	+44.05	-11.68	+48.68

a) All comparisons for 1980 to 1978 figures except plant 30009 and the industry average which are to 1979 data.

Table A-7

Energy Survey Results
Georgia Feed Mills-

Code Number	Ratio	1976	1977	1978	1979	1980
40001	BTU/1000 ton			351,891		233,197
	$/1000 ton			1.39		1.16
40002	BTU/1000 ton			335,926	458,251	301,927
	$/1000 ton			1.57	2.22	1.83
40003	BTU/1000 ton			26,946		23,788
	$/1000 ton			0.23		0.24
40004	BTU/1000 ton			144,676		
	$/1000 ton			0.62		
40005	BTU/1000 ton	222,071		212,238	218,864	205,038
	$/1000 ton	0.65		0.91	1.13	1.15
40006	BTU/1000 ton	132,820		208,191	171,971	149.577
	$/1000 ton	0.64		1.12	1.08	1.14
40007	BTU/1000 ton			10,791		
	$/1000 ton			0.21		
40008	BTU/1000 ton			28,301		
	$/1000 ton			0.49		
40009	BTU/1000 ton					174,630
	$/1000 ton					0.83
Average	BTU/1000 ton	177,446		186,676	291,013	178,331
	$/1000 ton	0.65		0.85	1.49	1.02

Table A-8

Percent Change Over Previous Year
Georgia Feed Mills

Code Number	Ratio	1977	1978	1979	1980
40001	BTU/ton				-33.73b
	$/ton				-16.55b
40002	BTU/ton			+36.41	-34.11
	$/ton			+41.40	-17.57
40003	BTU/ton				-11.72b
	$/ton				+4.35b
40004	BTU/ton				
	$/ton				
40005	BTU/ton		-4.43	+3.12	-6.32
	$/ton		+40.0	+24.18	+1.77
40006	BTU/ton		+56.75	-17.40	-13.02
	$/ton		+75.00	-3.57	+5.26
40007	BTU/ton				
	$/ton				
40008	BTU/ton				
	$/ton				
40009	BTU/ton				
	$/ton				
Average	BTU/ton		+5.20	+55.89	-38.72
	$/ton		+30.77	+75.29	-31.54

a) All 1978 figures are compared to 1976 values. No data available for 1977.

b) 1980 figures compared to 1978 results. No data available for these plants in 1979.

Table A-9

Energy Survey Summary: Georgia Broiler Processors

		Average	Range		Median
			Low	High	
1976	BTU/1000 lbs	1,407,811	783,254	2,032,285	1,278,445
(9)	$/1000 lbs	4.66	3.55	5.75	4.41
1977	BTU/1000 lbs	1,063,084	789,189	2,829,383	845,234
(8)	$/1000 lbs	4.23	2.88	11.38	3.61
1978	BTU/1000 lbs	834,639	707,297	1,085,032	826,278
(10)	$/1000 lbs	3.87	2.47	5.19	3.84
1979	BTU/1000 lbs	810,637	519,642	1,562,265	735,601
(9)	$/1000 lbs	3.88	2.23	6.74	3.84
1980	BTU/1000 lbs	553,183	475,559	655,301	524,305
(8)	$/1000 lbs	3.27	2.44	4.06	3.23

Table A-10

Energy Survey Summary: Georgia Egg Processors

		Average	Range		Median
			Low	High	
1976	BTU/1000 doz eggs	370,567	71,285	672,652	246,797
(5)	$/1000 doz eggs	2.09	0.86	4.14	1.64
1977	BTU/1000 doz eggs	278,092	75,104	401,019	258,043
(6)	$/1000 doz eggs	2.01	0.96	3.68	2.04
1978	BTU/1000 doz eggs	359,039	111,443	485,860	277,766
(5)	$/1000 doz eggs	2.99	1.34	4.77	2.33
1979	BTU/1000 doz eggs				
(0)	$/1000 doz eggs				
1980	BTU/1000 doz eggs	410,149	234,813	620,890	427,852
(2)	$/1000 doz eggs	3.24	1.46	5.38	3.42

Table A-11

Energy Survey Summary: Georgia Hatcheries

		Average	Range		Median
			Low	High	
1976	BTU/1000 birds	365,635	300,353	485,169	338,876
(6)	$/1000 birds	1.85	1.71	2.67	1.81
1977	BTU/1000 birds	431,216	141,540	724,787	286,911
(9)	$/1000 birds	1.27	0.97	2.68	1.45
1978	BTU/1000 birds	351,845	202,161	488,921	346,302
(8)	$/1000 birds	2.14	1.11	3.76	2.29
1979	BTU/1000 birds	320,832			
(2)	$/1000 birds	1.89			
1980	BTU/1000 birds	377,368	213,428	606,445	332,553
(9)	$/1000 birds	2.81	1.60	3.89	2.46

Table A-12

Energy Survey Summary: Georgia Feed Mills

		Average	Range		Median
			Low	High	
1976	BTU/ton	210,029	47,524	253,188	211,124
(7)	$/ton	0.74	0.34	1.12	0.69
1977	BTU/ton	190,834	135,502	247,988	183,427
(5)	$/ton	0.76	0.64	1.03	0.85
1978	BTU/ton	186,676	10,781	351,891	176,434
(8)	$/ton	0.85	0.21	1.57	0.77
1979	BTU/ton	291,013	171,971	458,251	218,864
(3)	$/ton	1.49	1.08	2.22	1.13
1980	BTU/ton	178,331	23,788	301,927	189,834
(6)	$/ton	1.02	0.24	1.83	1.15

Poultry Engineering Progress

Starting out as part of Tech's energy conservation effort in 1976, the Poultry Engineering Progress has evolved into a newsletter reporting on all Tech poultry related research. The Progress mailing list, just recently updated, includes 261 various poultry related industry, management and governmental groups in Georgia and throughout the United States.

The intent of the Progress is to keep the poultry industry and other related groups aware of and informed on Tech projects that can improve industry production and conservation practices. Figure A-1 illustrates a representative copy of the Poultry Engineering Progress.

poultry
engineering
progress

a newsletter of the technology/development lab
georgia tech engineering experiment station
atlanta, georgia 30332 (404) 894-3623

vol. 6 no. 2 May 1981

YIELD EVALUATION SYSTEM UPDATE

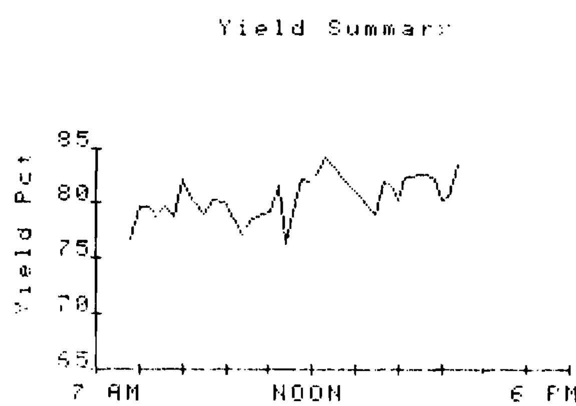
The Georgia Tech yield evaluation system is a computer-based measurement system designed to monitor and evaluate eviscerating line performance in poultry processing plants. A prototype system has been in operation at the Mar-Jac Plant in Gainesville and is providing Mar-Jac Plant management with useful production data. This project was funded by the Georgia Department of Agriculture through the efforts of the Georgia Poultry Federation.

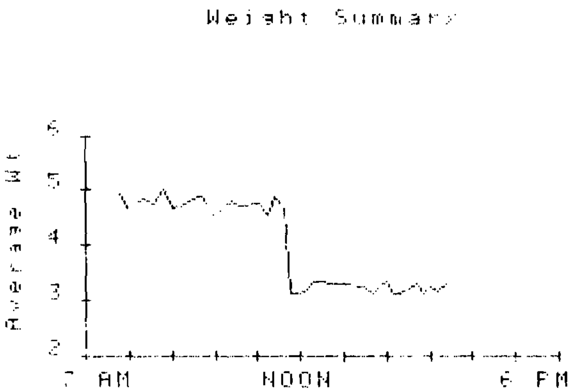
As the system is now operating, production data is updated about every 10 minutes and displayed on a video display terminal. Some information including line yield, average weight, number of birds processed, and total weight is also printed on a small strip printer every 10 minutes. At the end of the day, a summary of all data processed during the day can be graphed on a computer plotter.

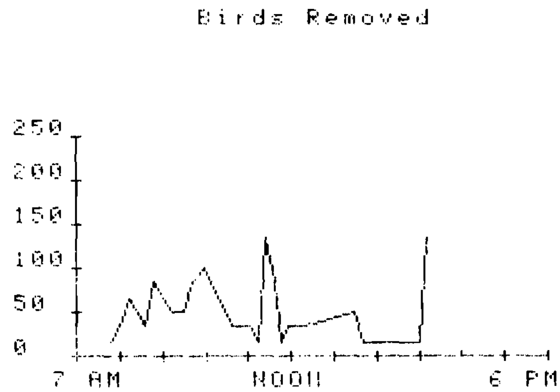
Examples of a typical daily data summary are shown below. Some interesting conclusions concerning the operation of the eviscerating line can be made from an analysis of this data. The weight summary graph shows that large birds for cut-up were processed in the morning, while small broilers were run in the afternoon. The yield summary clearly shows that on the average the yield for the broilers was better than the yield for the larger cut-up birds. The birds removed graph shows that more of the larger birds were removed from the line, which may indicate a problem with the larger birds. By analyzing the data daily, production problems can quickly and easily be identified and corrected.

DATA SUMMARY FOR 03/30/81

AVERAGE YIELD	80.5 %
AVERAGE WEIGHT	4.02 LBS
TOTAL WEIGHT	99475 LBS
BIRDS PROCESSED	23533
BIRDS REMOVED	1217







For further information on this study please contact:

Larry Moriarty
Technology Applications Laboratory
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

POULTRY INDUSTRY ENERGY AUDIT

We would like to thank all who responded to the Annual Poultry Industry Energy Audit for 1980. If you have not yet sent in your form or would wish to be included on future energy audits, please contact:

Chuck Ross
Technology Applications Laboratory
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332
(404) 894-3623

FIGURE A-1a

APPENDIX B

FINAL SPECIFICATIONS: HOT WATER STORAGE TANK FOR GOLD KIST, INC., ELLIJAY, GA.

Specifications for Hot Water Storage Tank
for
Gold Kist, Ellijay, Georgia

Provide one fiber reinforced polyester or equivalent vertical liquid chemical storage tank capable of storing at least 15,000 gallons of hot, potable water. The tank is to be insulated to prevent heat loss and the insulation should be covered as tank will be located outdoors.

Minimum vessel design criteria are listed on the enclosed specifications sheet. A fitting schedule is also enclosed. An engineering drawing is attached so all fittings and accessories can be located.

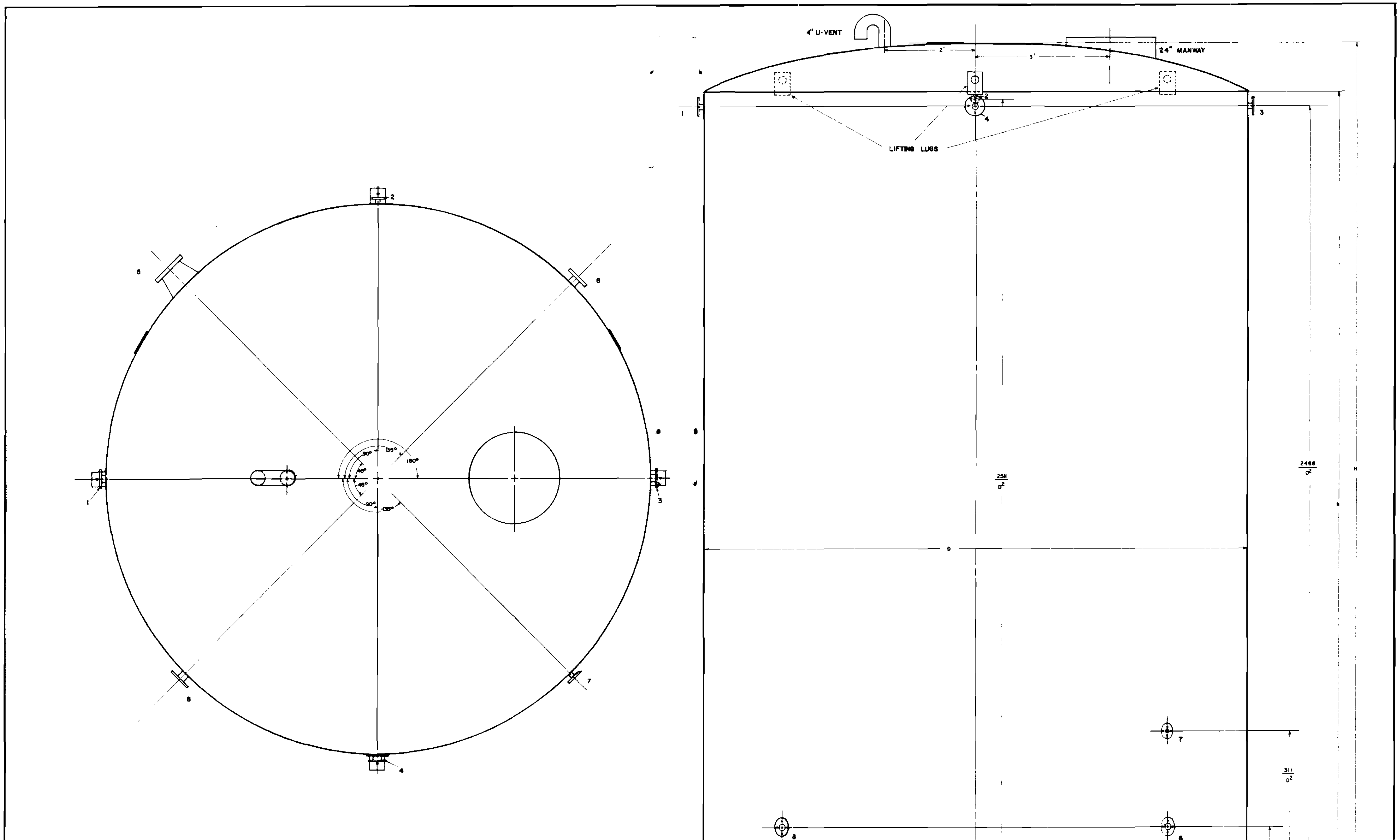
Before construction of the tank begins, the manufacturer will submit a shop drawing for approval by the purchaser. This drawing must include the followig specifications:

inner diameter, D
side wall height, h
total height of insulated tank, H
radius of dished top (uninsulated), r
location of all nozzles and accessories
(via engineering drawing(s))
total tank capacity
material used in constructing tank itself
material used to insulate tank
thickness of tank insulation
overall heat conductance, U, of tank
surface area of insulated tank
recommended tank operating conditions
manufacturer's recommended installation procedures
delivery date

The price quoted should include shipping. If your firm provides installation service, please quote an installed price. If you can provide neither shipping nor installation, please quote a price FOB from point of manufacture. An estimated time of delivery must accompany your price quote.

Table B-1
SPECIFICATIONS REQUIRED

I. Tank	
A. Loading Conditions	
1. Minimum wind load limit when anchored	100 mph
2. Concentrated top load limit	1000 lbs @ 10 psi
3. Snow load limit	25 psi
B. Chemical Storage Requirements	
1. Pressure	Atmospheric
2. Chemical to be stored	Hot, potable water
3. Specific gravity	1 to 0.97
4. Maximum temperature	190°F
C. Dimensional Requirements	
1. Minimum tank capacity	15,000 gallons
2. Approximate inner diameter	12'
3. Approximate straight shell height	17'6"
4. Approximate total height of insulated tank	18'6"
D. Construction Requirements	
1. Filament wound fiber reinforced polyester or equivalent	
2. Closed dished top	
3. Flat bottom	
4. Tank must be insulated with polyurethane or equivalent	
a) Approximate insulation thickness	1 1/2"
b) Approximate R value	R-9
c) Provide a skin or all-weather covering over insulation. Skin should be waterproof and protect insulation from ultraviolet radiation	
II. Accessories	
A. Flanged Nozzles	
1. Conically gussetted nozzles	
a) Bending strength requirement	1500 ft-lbs
b) Torque requirement	2000 ft-lbs
2. Flanged diameter and drilling	ANSI B16.5,150 lbs
3. Standard orientation has bolt holes straddling principal center line of vessel and radial line on tank top	
4. Minimum gasket requirements	40-50 durometer or equivalent, 1/8" thick, full-face
B. Vent	
1. Minimum vent diameter	4"
2. One vent required, located as per accompanying drawing	
C. Manway	
1. Hinged manway required, no gasket required,	



NOZZLE SCHEDULE		
No	TYPE	LOCATION
1	2" FLANGED	0°; $h = 2468/D^2$
2	1" FLANGED	90°; $h = 2511/D^2$
3	2" FLANGED	180°; $h = 2468/D^2$
4	2" FLANGED	-90°; $h = 2468/D^2$
5	4" FLANGED	45°; $h = 0$ NOTE: THIS IS A SIDE BOTTOM DRAIN
6	2" FLANGED	135°; $h = 213/D^2$
7	1" FLANGED	-135°; $h = 511/D^2$
8	2" FLANGED	-45°; $h = 213/D^2$
NOTE: ALL FLANGES ARE STANDARD ANSI B16.5, 150 lbs		

HOT WATER STORAGE TANK	
CONTACT: MIKE SMITH	Ph. (404) 894-3448
DR. BY JON THIBODEAU	
CK'D	APP'D
DATE 5-22-81	SCALE 1" = 1'

EES

FIGURE B-1 HOT WATER STORAGE TANK

located per attached drawing

2. Maximum manway diameter 24"

D. Tie Down Lugs

Provide four tie down lugs around tank base located 90° apart

E. Tank Lifting Lugs

Provide four lifting lugs; three should be located at top of straight shell and should be 120° apart, the fourth lug should be located at the base of the tank below the center top lug

F. Delivery

Manufacturer must provide estimated delivery time along with price quote. If manufacturer can arrange shipping please ship vessel prepaid and bill buyer on tank invoice.

G. Installation

If vendor does not provide installation service, he must provide recommended installation procedures for his tank.

APPENDIX C
SITE VISIT REPORT

TABLE C-1

SITE VISIT REPORT

VILLA RICA

BY: ______________

DATE: ______________

1. Gas Meter Readings:

   A. Solar House: __________________ B. Control House: ____________

2. Watt Meter Reading:

   A. Solar House: __________________

3. Age Chickens:

   A. Solar House: __________________ B. Control House: ____________

4. Recorder Paper:

   If Changed: ______________________ Next Date to be Changed: ____________

5. Recorder Tape:

   If Changed: ______________________ Next Date to be Changed: ____________

6. Batteries:

   If Switched: _____________________ Comments: ____________________

7. Batteries Integrator:

   If Charged: ______________________ Next Date to be Charged: ____________

8. Remarks: ____

____

____

____

APPENDIX D
INTERFACE SPECIFICATIONS BETWEEN HP-85 COMPUTER AND DATEL TAPE READER

This appendix contains the specifications of the interface between the HP-85 computer and the Datel Tape Reader. Included are the following items:

1) Wiring Code
2) Logic Levels
3) GPIO Interface Switch Configurations
4) Datel Logic Level Control

Wiring Code

HP-85
J1

Datel Tape Reader
J13

Pin	Mnemonic	Wire Color	Pin	Mnemonic
1	GND	Black	A3	GND
8	CTLA	White/Black	B4	WDT I
9	DA7	Grey	B10	DATA 5
10	DA5	Blue	B14	DATA 7
11	DAQ	Brown	B23	DATA 12
12	DA2	Orange	B25	DATA 20
13	GND	White	B3	GND
18	FLGA	White/Black/Yellow	B32	WORD RDY
19	RESA	White/Black/Orange	B5	INIT 1
21	DA6	Violet	B11	DATA 6
22	DA4	Green	B13	DATA 8
23	DA1	Red	B23	DATA 11
24	DA3	Yellow	B26	DATA 9

Wiring Code

HP-85 J2			Datel Tape Reader J13	
Pin	Mnemonic	Wire Color	Pin	Mnemonic
1	GND	Black	A6	GND
9	DB7	Grey	A28	ADD 8 0
10	DB5	Blue	A25	ADD 2 0
11	BBQ	Brown	A23	DATA 4
12	DB2	Orange	B17	DATA 2
13	GND	White	B6	GND
19	$\overline{\text{RESB}}$	White/Black/Orange	B1	STRT I
21	DB6	Violet	A29	ADD 4 0
22	DB4	Green	A26	ADD 1 0
23	DB1	Red	A22	DATA 3
24	DB3	Yellow	B16	DATA 1

Logic Levels

HP-85

OUTPUTS from the HP-85 GPIO are negative true
INPUTS to the HP-85 should be positive true

DATEL

OUTPUTS from the Datel are positive true
INPUTS to the Datel Should be negative true

The reason that negative true outputs from the HP-85 are used is that the RESA and RESB lines are used for the INITIALIZE and START inputs on the Datel. The RESA and RESB lines are pulsed by the CLEAR command on the HP. Therefore CLEAR 408 causes RESA to be pulsed and CLEAR 409 causes RESB to be pulsed. These lines are negative true which means that with positive true logic these lines will normally be high and will be pulsed low. Because of restrictions with the Datel, these lines must be held low and pulsed high. Therefore the outputs from the HP-85 had to be made negative true. This did not prove to be a problem in this application of the HP-85 since the only other output was the control (CTL) line. The CTL line logic is set separately by switch segment 52(8) in the GPIO interface.

GPIO INTERFACE SWITCH CONFIGURATIONS

Inside the GPIO interface are two switches: S1 and S2. Switch S1 has 4 segments and switch S2 has 7 segments all of which must be preset for proper operation. The switch settings are given below.

Switch Segments	Setting	Description
S1(2-4)	4	Interface Select Code
S2(1-3)	(*)	Device Address
S2(4)	0	Disables output on Parts A & B
S2(5)	0	Full handshake mode
S2(6)	0	Data line Logic Sense: Positive True
S2(7)	1	Flag Line Logic Sense: Busy=Lo; Ready=Hi
S2(8)	1	Control Line Logic Sense: Set=Lo Clear=Hi

*The device address is 08 which gives the following data transfer configuration:

Part A	LSB's
Part B	MSB's
Handshake Lines	CTLA/FLGA

This device address cannot be set with switch segments S2(1-3) since it only allows for device addresses of 07. Therefore, the device address must be specified for each interface instruction. (This switch was left in 06 which is the factory setting.)

DATEL LOGIC LEVEL CONTROL

J13 Pin	Mnemonic	Description	Level
B8	L CONT 1 I	Level Control 1, Inputs	Hi(+5V - A35)
B7	L CONT 2 I	Level Control 2, Inputs	Lo(GND - B9)
B28	L CONT 1 DATA 0	Level Control 1, Data & Address Outputs	Hi(+5V - A35)
B29	L CONT 2 DATA 0	Level Control 2, Data & Address Outputs	Lo(GND - B30)

NOTE: To get +5V on J13 Pin A35, jumper W1 was installed on the computer interface board in the Datel tape reader.